Mind Reading as Behaviour Reading:
Behaviour Analysis and Perspective Taking

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The chapters are presented in chronological order, following the way my study developed. The general introduction and research problem are provided in the opening section of Chapter 1. The subsequent chapters each begin with a chapter introduction that leads into a manuscript. This thesis includes three unpublished manuscripts (Chapters, 1, 2, and 4) and a published conceptual manuscript (Chapter 3). Chapter 3 takes the same form as the published paper. The synthesis of the research presented in Chapters 1 to 4 is provided in the final chapter (Chapter 5), titled General Discussion.

Abstract

Theory of Mind (ToM) presents perspective-taking as an ability to infer another person's mental state. Researchers in various fields have searched for evidence of ToM in both human and non-human subjects; however, this approach is highly "mentalistic," and rarely scrutinized in the relevant literature. Attempts to identify the behavioural functions of the stimuli involved in perspective taking are still in their infancy. My primary aim was to evaluate and further refine existing behavioural approaches to perspective taking. I focused on the environmental settings required for a person to engage in deriving a perspective of another person, and how the acquired stimulus functions are generalised to novel contexts. First, I examined the integrity of the concept of "deictic framing," which proposes that deictic expressions (I-You, Here-There, Now-Then) are the core components of perspective-taking behaviour, as defined within relational frame theory (RFT). Participants were first trained with the existing deictic-framing protocol with and without the deictic expressions. I then measured response generalisation using two different tasks designed to measure perspective taking: a visuospatial and an implicit relational assessment procedure (IRAP). No evidence of response generalisation to the other tasks was observed. Additionally, there was no difference in the performance of the participants in the two experimental groups, suggesting that deictic expressions do not have their claimed core status in perspective taking. Secondly, I examined the Relational Triangulation (RT) framework to investigate whether a specific stimulus function (i.e., perspective) would be derived in accordance with contextual stimuli bearing *same* and *oppositional* relational properties. The findings supported the broader applicability of the RT framework; however, there are many perspective-taking tasks that are beyond its scope. After considering the findings from these two experiments, I developed the proposition that we can treat perspective taking as problem-solving behaviour because there are considerable overlaps between the core behaviour relevant to various perspective-taking and problem-solving tasks, including stimulus generalisation of relevant stimuli, simple and complex discriminative stimulus functions, and relational responses. Based on this conceptual analysis, I hypothesised that a common false-belief task, the Sally-Anne test, can be represented and evaluated purely by using the concept of stimulus control. I used a conditional discrimination task in which reinforcement for identifying an individual's false belief depended on a stimulus change in a given setting. Participants completed a non-verbal computer task and selected a particular stimulus dependent on certain stimulus changes, replicating the conditional discriminative stimuli available in this false-belief task. Approximately 61% of participants in Experiment 1 and 88% in Experiment 2 successfully discriminated the pattern of stimulus changes. In conclusion, analysis of the stimulus functions involved in deriving another's perspective suggests that *mind-reading* is in fact a type of *behaviour-reading*. With this functional definition, we can help to address the practical challenge of resolving perspective-taking deficits in a range of contexts.

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A Publication from this Thesis

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Chapter 1

Experiment 1[1]

Deictic Framing Performance Fails to Generalise to Other Perspective-Taking Tasks

[1] Taylor, T., Sargisson, R. J., & Edwards, T. L. (2022). Deictic framing performance fails to generalise to other perspective-taking tasks. [Unpublished manuscript]. School of Psychology, University of Waikato.

General definition and conceptual understanding of perspective taking

Perspective taking is generally considered as the ability to understand that others may have different thoughts, motives, and feelings from one's own. The concept, which is commonly called "theory of mind" [ToM] (a term coined by Premack and Woodruff, 1978), was defined by Premack and Woodruff (1978) as follows:

> An individual imputes mental states to himself and to others (either to conspecifics or to other species as well). A system of inferences of this kind is properly viewed as a theory, first, because such states are not directly observable, and second because the system can be used to make predictions, specifically about the behavior of other organisms. (p. 515)

Perspective taking has also been called "mind-reading" (Apperly, 2011; Baron-Cohen et al., 1997). Perspective taking is regarded as a significant milestone of a child's cognitive development. Younger children start to communicate their needs and wants to others, and then later understand that others are different from themselves. This type of learning starts with differentiating one's own kinaesthetic and visual perspectives from others, by observing that other people move and function autonomously (e.g., moving one's own left arm does not result in another person moving their left arm). Over time, such basic discrimination learning progresses towards an ability to infer a perspective of another individual through abstract conceptualisation.

Various types of tests have been developed for gauging young children's ToM development (Table 1). The findings from studies administering such tests to young children indicate that, among typically developing children, ToM is acquired by about 4 years of age (Astington & Gopnik, 1991). However, the precise age of onset or development of ToM is debatable (Apperly, 2011; Onishi & Baillargeon, 2005). By measuring eye movement, Onishi and Baillargeon (2005) demonstrated that infants were able to pass a false-belief test, which is a complex ToM task (see Table 1, Level 5). Among atypically developing individuals, there is a delay to when they are able to pass the same type of perspective-taking task (refer to Peterson & Siegal, 1995; Peterson et al., 2000 [studies involving blind children]; and Russel et al., 1998 [study involving deaf children]). People with autism are considered deficient in this ability (Baron-Cohen et al., 1985, 1986).[2]

Table 1

Comprehensive Guide of ToM Tasks Adapted from Howlin et al. (1999)

Level	Task description
Level 1	An individual demonstrates the ability to identify self-perception and another person's perception through a simple visual perspective-taking task. For example, a two-sided card is held up between a child and a teacher, and the child is asked "what can you see, and what can I [the teacher] see?" The child receives feedback from the teacher, and if the answer is incorrect, a similar task is repeated until it is answered correctly. The feedback continues throughout all the tasks provided at different levels.
Level 2	An individual shows understanding in which a difference is not only what people see, but how it appears to them through a complex visual perspective-taking task. For instance, a teacher places a card flat on a table with an elephant picture on it between the child and the teacher; then the child is asked, "when I [the teacher] look at the picture, is the elephant right way up or upside down?" The visuospatial perspective-taking (Piaget & Inhelder, 1967) may overlap with the attributes described in the practice above at Level 1 and 2. Urberg & Docherty (1976) and Kurdek (1978) also proposed such an explanation of children's learning of perspective taking developing in succession. First, children construct a viewpoint that is likely to be similar to their own. Then, by the age of 5 to 6 years old, children can solve a complex perspective-taking problem involving "others" whose views are different from the child.
Level 3	A child shows an understanding of "seeing-leads-to-knowing" (Howlin et al., 1999, p. 240), meaning that people only know things that they have seen or experienced directly. It is assessed by playing a hiding game. For instance, a teacher hides an object (e.g., a pen) in a box while a child closes their eyes as instructed. The teacher then asks "Do you know what I hid in the box?" The child's answer is 'no', so the teacher asks, "Why don't you know what is in the box?" The correct answer is that the child does not know what's in the box because he or she has not seen it. A similar task is demonstrated using a doll to test the perspective of others and assess whether the child understands that "seeing-lead-to-knowing" applies to others as well (i.e., if the doll does not see the event, it is also unable to identify what is inside the box).

[2] Children with autism have difficulty passing false-belief tasks (e.g., Sally-Anne test, Wimmer & Perner, 1983). One possible variable affecting their poor performance may relate to a cognitive deficit in ToM ability (Baron-Cohen et al., 1985, 1986; Leslie & Frith, 1988), especially some degree of impairment in "conceptual" perspective-taking, which is the concept of "seeing-leads-to-knowing" (Baron-Cohen & Goodhart, 1994). Children with autism could pass the traditional "visuospatial" perspective-taking test (Hobson, 1983) and discriminated physical objects or human stimuli in the false-belief story (Baron-Cohen et al., 1986), but could not pass the conceptual aspect of the false-belief task.

Level	Task description
Level 4	A child predicts the actions of others based on a person's knowledge. This is assessed through questions such as "This morning, you saw a ball on the bed, not on the table. Where do you think the ball is?" The answer is "on the bed." Then, the child is asked to test their knowledge about the ball by being asked "why do you think it is on the bed?" A question in a similar scenario is asked using a doll, to test the doll's knowledge about the ball.
Level 5	A child predicts actions of others based on false beliefs, which is tested using the idea of unexpected transfer of an object, or unexpected contents of an object. Usually, a short story is provided to a child to assess their knowledge of false beliefs. For example, "Sally and Anne were in the room. Sally was playing with her marble and placed it in her basket and left the room. Then, Anne moved the marble into her box." The child is asked questions such as, "where does Sally think her marble is?" "where will she go to find it?" and "why does she think it is in the basket?" Another example uses a Smarties packet that contains a pencil. After a child acknowledges what is inside the sweet packet (seeing the pencil in the packet), a doll is introduced. The child is asked "here comes Rosie [a doll]. Rosie looks at the Smarties. What will she think is inside?" The correct answer is "sweets" or "Smarties."

Behaviour analysis and ToM

In comparison to the extensive volume of studies on ToM in the field of developmental and cognitive psychology, only a small amount of research has been conducted in the area of behaviour analysis. This could be because perspective taking is an umbrella term that refers to various kinds of covert and overt behaviours. Thus, a research question that investigates perspective taking may not be fundamentally different from questions generally posed by researchers in the field of behaviour analysis; for instance, under what conditions (i.e., identifying the relevant stimulus components and functions) does a perspective-taking response occur (Schlinger, 2017; Spradlin & Brady, 2008)? The difficulty in measuring private stimuli (Skinner, 1953, 1966) may also have been a major impediment to making advances in this area. However, the distinction between private and public events is unimportant because both are governed by the same behavioural principles (Palmer, 2009; Skinner, 1953). There are some technical limitations associated with measuring the relevant private stimuli; however, because of its emphasis on parsimony, behaviour analysis enables us to dissect the concept of ToM into functionally defined operants.

For example, in a "Guesser-Knower" perspective-taking task, an animal's ToM ability is tested by looking at whether or not the animal can use a pointing gesture by a "knower" to locate the correct container (i.e., the one which is baited with food; Catala et al., 2017; Maginnity & Grace, 2014; Povinelli et al., 1990). In a typical experiment, there are two human actors, one whose eyes are open (the knower), the other whose eyes are covered by a mask (the guesser). A container is baited by a third party in such a way that a dog cannot see which container is being baited, but the two individuals (guesser and knower) are visible to the dog. The guesser then points to one container, the knower points to another, and the dog is allowed to approach one container. Explanation of the dog's behaviour based on ToM would involve an assumption that the dog has some internal representation of what the guesser and knower can see. Parsimoniously, this event is about the dog emitting some kind of response (e.g., approaching and consuming food) in the presence of appropriate "cues" in a given context. The specificity of the cues varies depending on the experimental settings or characteristics of organisms; it could be the knower's open eyes, olfactory stimuli, influence of positional features, or it may be a matter of the ecological validity of the specific animal in the task (e.g., for many animals, eye contact tends to be threatening, as can unusual stimuli such as humans wearing a bucket or paper bag on their head; Maginnity & Grace, 2014).

Most studies investigating ToM are aimed at determining whether or not an organism is capable of generating an internal representation of others' perspectives, something which is often framed as an "all-or-none" construct (the organism either has it or does not). However, pragmatically speaking, how can we teach someone who is considered as deficient in this skill (i.e., individuals who do not pass the ToM task), or improve the current level of perspective-taking skill of a person who engages in it regularly (e.g., detectives, schoolteachers, counsellors, etc.)? To do this, it is essential to deconstruct the complex behaviour involved in perspective taking by examining the stimulus components, as defined by their functionality. This important aspect of identifying the functional relations participating in the events we call perspective taking will be elaborated further in Chapters 3 and 4. I will first explore existing behavioural theories and frameworks used to explain perspective taking. I will then further refine the behavioural interpretations of the topic and propose an alternative interpretation of the ToM concept from the point of view of behaviour analysis.

Studies on relations between ToM and verbal behaviour

To unravel what the core components involved in perspective taking are, some researchers have focused on the aspect of "internal representation" as a way to explain the relations between the concept of ToM and verbal behaviour, specifically questioning the extent to which verbal interactions contribute to accurate predictions of someone else's behaviour (Spradlin & Brady, 2008; Wellman & Lagattuta, 2004). For example, Astington and Jenkins (1999) and Ornaghi et al. (2011) have found a correlation between linguistic skills and success on ToM tasks. In ordinary life, parents tend to ask children a series of "what" and "why" questions about their own behaviour and the behaviour of others, such as "what are you doing? Why are you doing it? What are you going to do?" These types of conversational experiences help children relate to perspective-taking situations, such as false-belief situations, in which they can discriminate that others may be mistaken about reality, specifically by teaching them to tact how they think and feel, and learn how this may influence their accurate prediction of someone else's behaviour (Lohmann & Tomasello, 2003; Ruffman et al., 2002).

Relational frame theory (RFT), which is a behavioural account of human language and cognition (see Hayes et al., 2001), also explains the type of prediction associated with tacting the internal state of oneself or another. According to RFT, through conversational exemplars, children can learn how to respond to, and accurately predict, another person's behaviour (and their own) in more complex circumstances. RFT's approach to perspective taking is based on the concept of "self," which is considered to be a verbal construct. According to RFT, through multiple exposures to conversational exemplars, individuals eventually learn to discriminate the locus of "self" that is consistent through changes in environment (e.g., Mark who was 10 years old is now 35 years old, but his notion of "self" has remained constant even though his physical body has changed significantly). The concept of deictic relational framing is based on the idea that the relational function of "deictic expressions" such as *I, You, Here, There, Now,* and *Then* remain the same even if the referent (stimuli) in an environment changes. These expressions are said to play a fundamental role in perspective-taking behaviour (Hayes et al., 2001).

Development of the BH protocol

For training interventions and testing purposes, RFT researchers have developed a perspective-taking protocol consisting of a series of conditional sentences involving deictic expressions, with each followed by two interrogative sentences. The deictic protocol is often called the Barnes-Holmes (BH) protocol, in reference to the researcher who originally developed it. The structure of the BH protocol is designed in a manner that may align with the level of complexity proposed by Howlin et al.’s (1999) ToM tasks (Table 1). McHugh et al. (2004a, 2004b) attempted to validate the functionality of the BH protocol, demonstrating considerable overlap with the results reported in the other ToM studies; matching the rate of error responses observed in children’s performance involving the different types of tasks listed in Table 1, and following a similar progression with respect to the age at which ToM milestones are generally reached (McHugh et al., 2004a; McHugh et al., 2006, McHugh et al., 2007). Barnes-Holmes et al. (2001) claimed that training with the BH protocol is effective in establishing ToM-related verbal repertoires.

In the BH protocol, the Level 1 and 2 tasks involve a simple “relational frame” of I-YOU. The response to a question such as “What can you /I see?” is determined by the deictic contextual cue (i.e., the deictic expressions of I and YOU). In the third level of complexity, the training of the concept of “seeing-leads-to-knowing” involves the contextual control of I-YOU and NOW-THEN; for instance, “I did not see THEN so I do not know NOW” and “YOU saw THEN so YOU know NOW.” At Level 4, the relational frames I-YOU, HERE-THERE, and NOW-THEN are established to predict a true belief. For example, I saw your car next to the boat (HERE) this morning (THEN), so I think the car is THERE-NOW (i.e., the car is still located next to the boat). At Level 5, the false-belief attribution involves all three types of deictic contextual cues such as I-YOU, HERE-THERE, NOW-THEN (Barnes-Holmes et al., 2001).

Measuring the effectiveness of training interventions for improving perspective-taking performance

As a part of the investigation into identifying the structural constituents of ToM ability (i.e., questioning what divides children into those who pass and who do not pass a false-belief task), some researchers have studied the effectiveness of training interventions that may help young children who have failed false-belief tasks (see Table 1, Level 5). The interventions in the experiments usually involved teaching through verbal feedback and correction, with explanations as to why their answers were wrong (Clements et al., 2000; Lohmann & Tomasello, 2003). Children were encouraged to explain what happened in the false-belief event, usually prompted with several questions that allowed the child to see the aspect that was crucial to solving the task. For example, Slaughter and Gopnik (1996) taught children with an appearance-reality scenario using a golf ball made of soap. After presenting the golf ball, an experimenter asked the participants "What do you think this thing is?" The expected answer was "a golf ball." Then, after the participants had touched and smelled the golf ball, the experimenter asked, "Now what do you think this is?" The answer was "soap." After this step, the children were encouraged to predict the behaviour of a protagonist (e.g., a Snoopy doll who had not seen the event) based on the doll's currently held false belief (i.e., that the object was a golf ball), and their responses were corrected if wrong. The experimenter asked the children, "When you first saw this object, before you smelled it, what did you think it was?" This was followed by another question, "When Snoopy [the protagonist] first sees this thing, before he smells it, what will he think it is?"

Such studies demonstrated that young children can be trained to respond correctly in false-belief tasks (Appleton & Reddy, 1996; Lohmann & Tomasello, 2003; Melot & Angeard, 2003; Slaughter, 1998; Slaughter & Gopnik, 1996). However, the pre- and post-tests of these studies used similar scenarios to those provided in the training task, so some children may have passed the post-tests by simply relying on task-specific strategies. For example, children were screened for their ability to pass ToM tasks with a pre-test, such as by providing one of the classic object-transfer tests (e.g., the Sally-Anne test, see Table 1, Level 5). After the training intervention (such as the reality-appearance task from the above example), the effect of the training was evaluated by measuring the children's improvement in the performance with a post test, which was the same Sally-Anne test but with new stimuli (Slaughter & Gopnik, 1996).

To assess children's understanding of the concept of ToM, some researchers emphasize the importance of the demonstration of generalised responses to various "distant transfer tasks" (Charlop-Christy & Daneshvar, 2003; Knoll & Charman, 2000), which are tasks that differ significantly from the training task scenarios (such as training with a visual perspective-taking task, then using the Sally-Anne test as the post-test measure). In the application of the distant-transfer tasks, some researchers demonstrated that children did not improve their ToM performance. For example, after training with a Level 2 visual perspective-taking task (see Table 1), typically developing children (average age 4.5 years) did not show generalisation to an unexpected contents task (Knoll & Charman, 2000). Similar findings were reported in studies teaching children with autism, suggesting that these different tasks were not functionally equivalent (Okuda & Inoue, 2000; McGregory et al., 1998; Swettenham, 1996). These studies raise the question of the role of stimulus control and generalisation in ToM tasks in experimental settings.

There are only a small number of studies that have examined response generalisation after training with the BH protocol, followed by testing in a different context (Jackson et al., 2014; Lovett & Rehfeldt, 2014; Motoya-Rodríguez & Cobos, 2016; O'Neill & Weil, 2014). The results from these studies did not provide strong evidence supporting the generalisation of the BH protocol to other perspective-taking tasks. In my first experiment, I examined the generalisation of training with the BH protocol to different perspective-taking tasks. Participants were first trained using the BH protocol, and then any difference in the response accuracy in the other perspective-taking tasks was compared to the performance of the control group.

In addition to evaluating generalisation to other ToM tasks, I aimed to evaluate the extent to which "deictic" expressions play a significant (or even limited) role in perspective taking. It has been suggested that the BH protocol can be altered to use ordinary nouns (such as places, objects, or people) instead of deictic words (Hayes et al, 2001; Motoya-Rodríguez & Cobos, 2018), which calls into question the role of deictic elements takes in the protocol. Guinther (2017, 2018) also questioned the conceptualisation of the deictic framing theory. This argument is explored in further detail in the following manuscript, but as a brief explanation here, Guinther pointed out that deictic framing does not entail any relational component that constitutes relational frame theory. Therefore, I investigated whether or not the deictic components in the BH protocol are fundamental to perspective taking. I did this by arranging two experimental groups who were trained with BH protocol; one with deictic expressions and the other without. If, as claimed, deictic expressions are the core component in perspective taking, then the relevant relational functions based on the deictic framing should facilitate generalised responding in some of the dissimilar tasks, especially for those who have been trained with the BH protocol (i.e., one would expect to see higher accuracy in their performance). The following manuscript discusses the findings from the experiment on response generalisation after the training intervention with the BH protocol, and also questions the integrity of the conceptual framework of deictic framing and the BH protocol.

Deictic Framing Performance Fails to Generalise to Other Perspective-taking Tasks

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Abstract

The behavioral processes underlying perspective taking have not been studied extensively. One approach to understanding and enhancing perspective taking, deictic framing, has been proposed. Proponents of this approach have suggested that deictic framing is a core property of perspective taking. A training protocol based on deictic framing has been developed and tested, but researchers generally evaluate the effectiveness of the protocol using tasks that have a similar format to the training protocol. Little research has examined the protocol's effectiveness for improving performance in different perspective-taking tasks. We investigated generalization of the performance of three groups of university students trained with a deictic-framing protocol (or not) and tested with two other perspective-taking tasks: a visuospatial perspective taking using a cupboard containing a range of objects and a version of the Implicit Relational Assessment Procedure specifically designed to measure perspective taking. The first group was trained with the original verbal protocol with deictic expressions; the second group with the same protocol involving non-deictic words; and the third group was merely exposed to deictic expressions as a control condition. The result suggested that deictic framing is not fundamental to perspective taking, as the performance of the two experimental groups was not significantly different from the control group's performance. Identification of specific stimulus functions involved in successful perspective taking and how those functions can be established should be addressed in future research.

Key words: theory of mind, perspective taking, deictic framing, relational frame theory

Deictic framing performance fails to generalize to other perspective-taking tasks

Perspective taking is an ability of critical importance that helps people establish and maintain relationships, negotiate deals, predict the actions of others, and achieve a wide variety of other valuable outcomes. Perspective taking has been defined as an ability to perceive another person's situation by "spontaneously adopt[ing] the psychological point of view of others" (Davis, 1983, p.114). Premack and Woodruff (1978) coined the term "theory of mind" (ToM), theorizing that people rely on mental attribution to predict what other people may think, believe, feel, or otherwise experience.

Under the rubric of relational frame theory (RFT; Hayes et al., 2001), some researchers have proposed "deictic framing" as a core component of ToM (Barnes-Holmes et al., 2004). RFT was developed as an extension of Skinner's (1957) original functional account of verbal behaviour to include "the action of framing events relationally" (Hayes et al., 2001, p. 43). The theoretical framework is based on "a generalized pattern of arbitrarily applicable relational responding (AARR); that is, relational responses that are not based solely on the formal properties of the stimulus relations" (Barnes-Holmes & Harte, 2022, p.3). According to RFT, AARR is characterized by three defining relational properties: mutual entailment, combinatorial entailment, and the transformation of stimulus functions.

There are multiple types of AARR (Hayes et al., 2001, p. 35). Relational responding in coordination, for example, entails a quality of sameness or *stimulus equivalence* (e.g., A "is" B, or A "is similar to" B)[3]. Another example of relational responding is a frame of distinction (e.g., A "is different from" B). Hayes (2001) proposed that children learn such frames through questions presented by a verbal community, sometimes explicitly through educational programs (for instance, "one of these things is not like the others; one of these things does not belong; can you guess which thing is not like the others?"). Responding to such exercises in everyday life, children eventually develop derived relational responding of similarity or distinction among stimuli in the presence of specific contextual stimuli, which indicates when a type of relational response is likely to be effective.

[3] According to RFT, Sidman's stimulus equivalence (Sidman & Tailby, 1982) is an example of relational frames, such as the "frames of coordination."

The application of the *correct* relational response under the relevant contextual control is reinforced by the verbal community, or by some other outcome of the relational response (such as the ability to solve a problem). The specific contextual stimuli, which are sometimes explicit (e.g., “is similar to” or “is different from”) and sometimes subtle (e.g., contexts in which causal relational responding such as “X causes Y”), evoke AARR which can then be applied to novel stimuli in different contexts. One proposed type of relational responding, *deictic* relational framing, specifies a relation from the perspective of a speaker, and is controlled by deictic cues such as *I* vs. *You*, *Here* vs. *There*, and *Now* vs. *Then*. Some researchers have suggested that deictic framing is fundamental to perspective taking and ToM, and that understanding this type of relational responding will advance our understanding of perspective taking (Dymond & Barnes, 1997; Hayes, 1984; McHugh et al., 2004a).

Barnes-Holmes Protocol

RFT researchers have developed a perspective-taking protocol (sometimes referred to as the Barnes-Holmes protocol [BH protocol], named after the creator of the list) based on the concept of deictic framing (see Hayes et al., 2001; McHugh et al., 2004a, 2004b). The protocol has 62 verbal tasks that include deictic components (e.g., I, you, here, there, now, then). The tasks increase in three levels of complexity from simple to reversed to double-reversed (McHugh et al., 2004a, 2004b). In a simple task, the participant only needs to identify contextual information provided in a sentence. For example, they are told, “I have a red brick, you have a green brick” and are then asked, “What do I have? What do you have?” In a reversed task, a conditional statement such as “If I were you and you were me” is provided in addition to the simple task, so the correct answer would be “I have a green brick” and “you have a red brick.” Lastly, a double-reversed task might be: “I am sitting here on a black chair and you are sitting there on a blue chair, if I were you and you were me, and here were there and there were here, where would you be sitting?” The *correct* answer is “here on a blue chair.”

McHugh et al. (2004a) conducted one of the first studies testing the protocol with people from different age groups (five groups in total: 18–30 years [adulthood]; 12–14 years [adolescence]; 9–11 years [late childhood]; 6–8 years [middle childhood]; and 3–5 years [early childhood]) to investigate whether the performance data were consistent with the developmental profile commonly found in ToM studies (i.e., the rate of error responses decreasing as a function of age). In the simple trials, all participants performed with high accuracy, except for those in the early childhood group, who performed with low accuracy. Other childhood groups (6–8 and 9–11 years) produced more errors (50–70%) in the reversed and double-reversed trials compared to the adult group (30–40%). The early childhood group did not perform well on complex trials, with a mean error rate of 80–90%. In addition, of the three deictic components, participants' performance on *Now-Then* was lower than on *Here-There* and *I-You* trials. The authors pointed out that their findings correspond with the progression of development of ToM.

RFT Deictic Framing Training Studies

The BH protocol has been used in various empirical investigations for assessing and training both typically developed children aged 4 to 7 years (Davlin et al., 2011; Heagle & Rehfeldt, 2006; Montoya-Rodríguez & Cobos, 2016; Weil et al., 2011) and atypically developed children and adults, including those considered to have deficiencies in perspective-taking ability. This includes individuals with autism aged 6 to 18 (e.g., Barron et al., 2018; Belisle et al., 2016; Gilroy et al., 2015; Jackson et al., 2014), high-functioning autism aged 6 to 18 (e.g., Lovett & Rehfeldt; 2014; Rehfeldt et al., 2007; Tibbetts & Rehfeldt, 2005), schizophrenia (O'Neill & Weil, 2014; Villatte et al., 2010), and social anxiety disorder (Janssen et al., 2014).

Some researchers have investigated whether learning the BH protocol leads to higher performance in other ToM tasks, such as Howlin et al's (1999) Level 3 *seeing-leads-to-knowing* task (sensory *attending* or *seeing* is understood as knowing), the Level 4 task for an ability to predict actions based on true belief, or the Level 5 task to teach an ability to predict whether people can act on the basis of a false belief. Other ToM tasks have also been used, including the Unexpected Contents task (or sometimes called the "Smarties" or "M&M" task),[4] Hinting task,[5] and Theory of Mind

[4] This task is designed to test the participant's ability to identify a false belief. For example, a box of crayons is shown to participants who are asked what they think is inside. Then, the experimenter reads the following statement: "If I put the pencils in a chalk box and you are not here, you would think the chalk box contains chalk." The participant is then prompted to answer true or false.

[5] The ToM Hinting task has 10 short scenarios describing interactions between two characters. For example, "Stephanie says to her friend Nicole: 'I can't afford the repairs on my car. Could you lend me some money?' Nicole answers: 'I have to have my car repaired too.'" Then, the participant is asked "What does Nicole really mean when she says this?" Then a second hint is provided; "Nicole then says 'The repairs to my car are going to be very expensive.'" The participant is again asked, "What does Nicole really mean when she says this?"

Inventory (ToMI).[6] However, training with the BH protocol does not typically influence other ToM measures. To date, few studies have reported generalization of the skills acquired from training with the BH protocol over to different ToM tasks. For example, following training with the BH-protocol, O'Neill and Weil (2014) demonstrated an improvement in performance by all three participants with schizophrenia in both the Unexpected Contents Task and the Hinting Task (although one of the three participants was unable to complete the final session of the Hinting Task and the other two participants scored less than 80%). In contrast, no improvements were observed in Howlin et al.'s (1999) Level 3 to 5 ToM tasks following training with the BH protocol (Jackson et al., 2014; Lovett & Rehfeldt, 2014; Montoya-Rodríguez & Cobos, 2016; O'Neill & Weil, 2014; Weil et al., 2011). None of Jackson et al.'s (2014) participants (three children with autism) improved their scores on the ToM tasks after the BH protocol training. In Weil et al.'s study (2011), only one of three normally developing children showed improvements for the ToM tasks after deictic training (Weil et al., 2011). Lovett and Rehfeldt (2014) used ToMI to examine the effect of mastering the BH protocol among three young adults with Asperger syndrome. The scores did not change between the pre- and post-training probe trials designed to assess the effect of the training intervention.

Critical Analysis of the BH Protocol Deictic Frame

The term *deixis* comes from the Greek word meaning *pointing out* or *drawing attention to* (Harman, 1990). According to the Oxford dictionary of English, the word *deictic* is defined as an "expression whose meaning is dependent on the context in which it is used such as here, you, me, that one there, or next Tuesday" (Oxford University Press, n.d.). If a deictic word such as *there* is presented without additional contextual information, it will not make sense to a listener (i.e., they will not be able to respond effectively). Deictic statements must be accompanied by additional contextual cues, such as the presence of an item of discussion when the word *there* is spoken. These cues may also be provided directly by the speaker (e.g., a pointing gesture to a broken window when saying *that* in a crowded workshop). Without these other cues, the listener would have difficulty responding appropriately to the verbal statement.

[6] ToMI includes 48 items assessing inferences about emotion and belief based on caregiver reports that reflect the caregiver's evaluation of the perspective-taking ability of adolescents with autism.

Deictic cues were described as a critical element of perspective-taking ability in the original RFT conceptual work explaining perspective-taking ability (Hayes et al., 2001). In addition, some RFT researchers have specified that deictic cues function as “deep grammar,” influencing all other framing to produce what we know as perspective taking (Hayes et al., 2001, p. 124). Hayes et al. (2001) explained “deictic” relational framing as follows:

> The frames of I and You, Here and There, and Now and Then…are unlike most of the other relational frames in that they do not appear to have formal or non-arbitrary counterparts…Frames of perspective have no simple nonverbal counterpart, and must be taught through demonstration and multiple exemplars without any use of formal properties. For that reason, they are sometimes called ‘deictic’ relations—literally, demonstrative relations that must be ‘shown directly’—but these relations are anything but direct. (p. 122)

This description suggests that RFT researchers use “deictic” somewhat differently to how linguists use the term. The conceptual framework is also somewhat unclear. Hayes et al. (2001) emphasized the strictly arbitrary nature of this particular relational frame but, in the same work, stated that we can replace the deictic cues with non-deictic nouns (i.e., it is fine to use “Emily” instead of “you” or “Burger King” in place of “there”) in the deictic training protocol. This appears to contradict the conceptual view of proponents of deictic framing and linguists with respect to the notion of “deictic expressions,” whose meaning changes depending on the context in which they are used (e.g., “there” will change in meaning depending on where the speaker is pointing or looking but “Hamilton, New Zealand” will not change).

In some of the studies where BH protocols were used as an intervention to improve participants’ perspective-taking ability, researchers modified the text of the protocols, replacing some of the deictic expressions with familiar character names and their actions from stories or cartoons familiar to participants, such as Cinderella and SpongeBob (e.g., “You are waiting for recess and Cinderella is dancing at the ball, what are you doing? What is Cinderella doing?”; Devlin et al., 2011, Gilory et al., 2015, Heagle & Rehfeldt, 2006; Montoya-Rodríguez et al., 2017). Participants in these studies were mainly examined for the demonstration of stimulus generalization by increasing their response accuracy in the slightly modified BH protocol tasks, which were provided using stories different to the one used in the training session. Some questions arise over the validity and utility of the concept of deictic framing and the BH protocol. What is controlling perspective taking if the deictic words, which are defined as the main contextual cues, can be swapped with other non-deictic words? If the BH protocol contributes to the acquisition of "deep grammar," why do many studies fail to show response generalization to different ToM tasks?

Guinther (2017) pointed out what appears to be a theoretical flaw in the concept of deictic framing: deictic framing does not entail any relational component that constitutes relational responding. Guinther noted that, "in contrast to the relatively straightforward entitlement and transformation markers of other relational framings, it is at present unclear how I-you, here-there, and now-then deictic relational framings are to be functionally identified under tightly controlled conditions" (p. 449). The three types of entailments explained earlier (mutual entailment, combinatorial entailment, and transformation of stimulus functions) do not seem to be applicable to deictic framing. For example, there appears to be no mutual entailment between "I" and "You" unless in the context of some additional framing, such as coordination framing (e.g., once we learn the unusual relation "I" am "You," then the relation "You" are "Me" may be derived). The functionality associated with the deictic expressions could be defined by other relational framings, but nothing would be entailed by the deictic framing. For example, "I am to the left of you and you are to the right of me," indicates the spatial cues (i.e., "left of" and "right of") that are required to derive other relations (the relative location) between the stimuli, and "I" and "You" just happen to be the stimuli participating in the frame. In addition, without being specified by "if…then" conditional framing, we would not be able to do *perspective taking* as it is defined in many tasks, including the BH protocol, to predict or intuit the knowledge or behavior of others (e.g., If you were me and I were you, what would you be doing and what would I be doing?). It appears that the *work* the participant is doing in such a protocol is solving the if-then puzzle, which can be done by attending to the reversal cues. Substituting nonsense stimuli for "I," "You," "Here," or "There," does not seem to fundamentally change the puzzle. However, an empirical analysis is required to test this hypothesis. Clarification is required to find out whether deictic framing has been conceptualized coherently within RFT, and to discover the role of deictic expression in perspective taking from a functional language perspective.

The current study may help to clarify some of the questions regarding the theoretical assumptions of the concept of deictic framing, and shed light on the features of the protocol that are responsible for its effectiveness (or lack thereof) in improving perspective taking. To investigate the effectiveness of the deictic components of the protocol, we compared the effects of training in three different groups:

1) BH+ group, a group of university students who were trained using the existing BH protocol (see Appendix A);
2) BH– group, a group of students who were trained using a modified version of the BH protocol with specific nouns (e.g., “Burger King,” “Orange,” etc.) instead of deictic expressions (see Appendix B); and
3) A control group of students, who were exposed to parts of the original BH protocol with deictic expressions, but without the problem-solving part of the protocol. The members of the control group were simply asked to select a deictic word used in a given sentence (see Appendix C).

The dependent variables were a tally of participants’ correct responses on an activity indicating their visuospatial perspective-taking, a “cupboard task” that involved moving items in a cupboard in response to instructions from someone who could only see some items in the cupboard, and a version of the Implicit Relational Assessment Procedure (IRAP) specifically designed to measure perspective taking (self vs. others). For the latter task, the performance of each group (i.e., number of correct responses and latency) was recorded and analyzed to determine if the training produced any differences between the groups. Raven’s Progressive Matrices (RPM) were also administered before introducing participants to the BH protocol to evaluate the degree to which the results of this test were predictive of performance in the other measures, including performance with the BH protocols. Given that, conceptually, deictic expressions do not appear to play a critical role in the BH protocol, if the BH protocol is effective in producing general perspective-taking improvements, we predicted that the experimental groups (the BH+ and BH– groups) would perform better than the control group on both of the cupboard task and the IRAP task but that the performance of the experimental groups would not differ significantly from each other.

Method

Participants

A total of 90 university students was recruited, with 30 participants randomly assigned to each group: 1) a deictic (original Barnes-Holmes protocol) group (BH+); 2) a non-deictic Barnes-Holmes protocol group (BH–); and 3) a control group. Students were recruited through advertisements on bulletin boards around the University of Waikato. Participants chose either course credit (1% for each hour of participation) or entry in a draw to win one of five $50 vouchers that could be spent at a local store upon completion of the experiment.

Experimental Tasks

Raven's Progressive Matrices

Raven's Progressive Matrices (RPM) are 60 visual-puzzle tasks measuring analogical reasoning and problem solving, and are generally used for assessing "intelligence" (Raven et al., 1984). A participant is presented with geometrical figures, which each have one part missing, and then selects the correct answer from six alternative options. We provided participants with a booklet of problem items and a piece of paper where they filled in their answers to the multiple-choice questions. Validity studies indicate that correlations with the RPM and several subtests of the Wechsler Adult Intelligence Scale–Third Edition range between 0.75 and 0.88 (Lezak et al., 2004). Internal consistency was found to be 0.89 and split-half reliability was 0.91 (Cotton et al., 2005). In another study done in Kuwait, the test-retest reliability (n = 969 aged from 8 to 15 years) was between 0.88 and 0.93 (Abdel-Khalek, 2005). RPM is commonly used as a measure to explore the effects of relational training on cognitive abilities in RFT research (see Janssen et al., 2014; Thirus et al., 2016; Villatte et al., 2010); however, we treated RPM as a covariate.

Visuospatial "cupboard" Perspective-taking Task

The visuospatial perspective-taking *cupboard* task was implemented in the manner described by Keysar et al. (2003) and Ferguson and Cane (2017) to assess adults' perspective-taking abilities. We designed our task to investigate the extent to which participants behaved in accordance with information that the person giving instructions had access to, which is demonstrative of one form of perspective taking. The task involved a *cupboard*, a piece of furniture containing 16 cells (in a 4-x-4 layout), with the view of some of the cells occluded from one side of the cupboard but not the other (Figure1).

Figure 1

Shelf Used to Display Item in the Visuo-Spatial "Cupboard" Task

Note. From one side—the *open* side—a participant could see all the objects placed in the cells, but from the other side, only a subset of the cells could be seen.

Five cells were occluded from the experimenter's (i.e., director's) view, and the other 11 cells were mutually perceptible from both the participant's and the director's view. Each cell was 16 cm high, 18 cm wide, and 15 cm deep. The participant sat on the open side of the cupboard and followed a set of instructions given by the director, which instructed them to pick a target object and move it to another cell in the cupboard. The participants could view all the objects placed in the cupboard, but some cells were occluded from the director's view. Thus, the accuracy of the participant's performance in perspective-taking was determined by their ability to follow instructions correctly according to the information to which the director has access (i.e., they had to take into account which cells were visible to both them and the director, and which cells only they could see). To perform well on this task, participants had to correctly respond to the trials with critical paired items that had *ambiguous* names (e.g., an instruction contained a word such as "candle" but there were two candle-like objects in the array: a glass jar candle in an open cell, and a pillar candle in an occluded cell). For comparison, we included trials with baseline objects (i.e., a range of objects unrelated to each other) to show participants' performance under normal conditions without any ambiguous pairings (e.g., given a glass jar candle and a yoyo, in a baseline trial the participant would respond correctly by reaching for the candle when asked to move the object called “candle”). Some objects were displayed in open cells, and some were in occluded cells. In the first session, participants started with four critical trials of ambiguous objects where eight objects with ambiguous names were placed in the cupboard. In Table 1, the list of the trial orders from 1 to 4 in the left column indicates which pairs of objects were used in each trial with the ambiguous objects. The trials with unambiguous objects followed the first critical session, in which eight unrelated objects were randomly placed in the cupboard (see Table 1 in the right column, Trial order 5 to 8). The remaining two sessions were provided in the order described above, with Trials 9 to 12 using ambiguous objects, and Trials 13 to 16 using unambiguous objects. Two separate video cameras (one positioned at the right side of the participant, and the other one behind them) captured the movement of the participant's arms (e.g., movements like reaching and moving an object to the left, right, above, or below its current position among the 4-x-4 squares of the cupboard).

Table 1

Objects Placed in an Array of Cells with either Occluded or Open Views during Critical or Baseline Trials

Critical trials with ambiguous objects			Baseline trials with unambiguous objects		
Trial order	Occluded cell	Open cell	Trial order	Occluded cell	Open cell
1	Pillar candle	Glass jar candle	5	Yoyo	Glass jar candle
2	Glue bottle	Glue stick	6	Toy furniture (a rocking chair)	Glue stick
3	Large measuring cup	Middle and small sized measuring cup	7	Notebook	Middle and small sized measuring cup
4	A paper cup	An egg cup	8	Toy furniture (a bed)	An egg cup
9	Safety pins	Hair pins	13	Candies	Hair pins
10	Hairbrush	Paintbrush	14	Toy furniture (a piano)	Paintbrush
11	Water glasses	A pair of glasses	15	Toy furniture (a table)	A pair of glasses
12	Wood stick	Lip balm (Chap Stick)	16	A Lego figurine	Lip balm (Chap Stick)

Implicit Relational Assessment Procedure

The IRAP was developed under the rubric of RFT (Barnes-Holmes et al., 2006) to detect relational framing based on a latency response measure. It is a computer-based task where participants respond to a series of paired stimuli (often words and images) by selecting true or false in response to whether a pair of stimuli are consistent or inconsistent with the participant's historically coherent relational network (i.e., those relational responses that they are likely to have learned to a high degree of fluency). The participants are encouraged to respond both quickly and accurately within specific time limits to meet an accuracy threshold. The IRAP consists of practice blocks (usually three paired blocks of consistent and inconsistent trials, each block containing about 24 trials) and test blocks (six paired blocks of the consistent and inconsistent trials, containing 24 trials each). All response latencies are recorded in the IRAP and are used to calculate the D-IRAP score. The score is a normalized index of raw IRAP response latency, which is similar to Cohen's effect size (Cohen's D).

The outcome data are used to evaluate whether the observed differences in average response latency between consistent and inconsistent blocks are large enough to conclude that there is a difference between the two. The larger the D score value, the bigger the effect size (e.g., 0 is no effect, and above 0.8 indicates a large effect size).

The IRAP has been used to investigate perspective-taking abilities, specifically for comparing responding to "self" vs. responding to "other" stimuli (Barbero-Rubio et al, 2016; Kavanagh et al., 2018). In the perspective-taking IRAP test, participants are exposed to a sample stimulus that is either "I," or an experimenter's name, such as "Mary," which represents the perspective of "other." Another stimulus is presented at the bottom of the screen, showing a description of an action such as "standing near the desk," "sitting on the chair," or "staring at the computer monitor." The participants answer "Yes*"* or "No*"* in accordance with arranged rule-following conditions that are either consistent (pro-self-perspective) or inconsistent (pro-other-perspective). Participants in these experiments were slower to take the perspective of others, supporting the generally held notion that people are faster at responding from a pro-self perspective, and slower when responding from the perspective of others.

We used Open Source IRAP software (https://doi.org/10.17605/OSF.IO/KG2Q8). During each trial, the software displayed the text "I" or "Tokiko" (the experimenter's name) at the top of the screen. Below the sample words was 1 of 12 words and phrases describing the activities of either "I" (i.e., the participant) or "Tokiko," and these sample and action words appeared simultaneously. The six action words belonging to "I" were "seated," "participant," "with keyboard," "looking at screen," "here," and "blue Post-it." The six words describing "Tokiko" were "standing up," "experimenter," "holding a pen," "holding a notebook," "there," and "pink Post-it." These were the same words used by Barbero-Rubio et al. (2016). In the lower left and right corners of the screen, the software displayed "PRESS 'd' FOR [Yes/No]" and "PRESS 'k' for [Yes/No]" with the position of the words "Yes" and "No" randomly assigned to the left or right in each trial.

Prior to each block of 24 trials, the program displayed the message "answer as if you were you and Tokiko were Tokiko" (consistent block) or "answer as if you were Tokiko and Tokiko were you" (inconsistent block) in the center of the screen and, below the message, "press the spacebar to proceed." The 24 trials contained four trial types: I / I's actions ("I" sample stimulus and words descriptive of the participant), I / Tokiko's actions, Tokiko / Tokiko's actions, and Tokiko / I's actions. The specific stimuli corresponding with each of the four trial types were randomly selected for each trial. In each trial, the participants were presented with the trial stimuli and, if a response did not occur within 2000ms, feedback in the form a red exclamation mark ("!") appeared in the center of the screen. The participant could still respond at any time after the "!" had appeared. The presentation of latency feedback was programmed to start from the second pair of blocks in the practice phase. In all trials, if an incorrect response (i.e., a response that did not correspond with the rule for that block) occurred, a red "X" appeared in the center of the screen, and the trial stimuli remained in place until the correct response occurred. The inter-trial interval was 400ms.

Interobserver Agreement

A second observer watched video footage of each participant's performance on the cupboard task. The video footage was selected from seven individuals who were randomly selected from each group of three, which covered 21% of the total participants (21 of 98). A block of probe trials completed by each participant had a total of 16 probes, and the responses were recorded as correct (1) or incorrect (0). Inter-observer agreement was calculated on a trial-by-trial basis, by dividing the total number of agreements by the total number of test trials offered, then multiplying by 100. Agreement for the correct or incorrect responses in the test trials ranged from 94% to 100%.

Procedure

The experimental sessions were conducted in a room in the presence of an experimenter. We asked participants to attend two separate sessions. In the first session (Day 1), RPM was administered. In the second session (Day 2), participants completed the visuospatial "cupboard" perspective-taking task and the IRAP. Between the two sessions, all participants completed a series of online training tasks that were available through the University's online learning management system (Moodle). We instructed participants to complete the training tasks any time, within 3 days after the first session. The duration of each task was approximately 15 minutes or less, with each containing 15 questions. Participants completed four of these tasks in total. After completion, the correct answers were shown to the participant.

On Day 1, all three groups followed the same procedures. Upon a participant's arrival at the experimental room, they took a seat, received a briefing of the experimental information by the experimenter, and signed a consent form. The participant took the RPM test and was handed a sheet to fill in answers to each of the 60 questions. The test took between 15 and 40 minutes to complete.

After taking the test, the experimenter informed the participants about the online training that they were to complete before returning for the Day 2 session. They were also informed that they could take the online training at any time and from anywhere with internet access using a device capable of running a Google Chrome or Firefox browser, but that all the self-learning training had to be completed within 3 days. To ensure the participants' understanding of the online training performance requirement, the experimenter showed the participants three example questions from the BH protocol, one of each trial type (simple, reversed, and double reversed), on the monitor. The experimenter asked the participant to answer each question and then provided feedback (correct or incorrect) for each response immediately. For group BH+, the experimenter introduced the deictic protocol (see Appendix A) used by McHugh et al. (2004a). For group BH–, the experimenter introduced a non-deictic protocol that we adapted from the original protocol (see Appendix B). For the control group, the experimenter introduced the original deictic protocol with all the *problem-solving* components removed, and trained the participants to perform a simple identification task (see Appendix C). The participants were asked to complete a total of four tasks of 15 questions, during the 3-day period. They had to repeat each training task if they did not meet the criteria of more than 90% correct within 5 minutes for the 15 questions. The participants' answers were automatically evaluated, and feedback was provided. Their completion of the training was monitored by the experimenter. Lastly, the participant booked another appointment for Day 2 within 5 days.

On Day 2, upon the participant's arrival in the same room used in the Day 1 session, they first completed the IRAP task. The experimenter asked the participant to put a blue Post-it note on their arm or chest (where the participant could see it) and the experimenter put a pink Post-it note on her own chest. The experimenter then positioned herself near the participant, who was sitting in front of the desktop computer in the room. The experimenter ensured that participant could see the experimenter wearing the pink Post-it and held a pen and a notebook in her hand while the participant worked on the IRAP task. The order of the IRAP was alternated to check for order bias: the consistent-trials-first group (*n* = 45) was presented with “if you were you and Tokiko were Tokiko” first. The inconsistent-trials-first group (*n* = 45) was presented with “if you were Tokiko and Tokiko were you” first. Within each of the three groups, the participants were randomly assigned to the two IRAP orders.

After completing the IRAP task, we asked the participant to move over to the 4-x-4 cupboard, which had a drape covering it completely from view. The participant was seated on the side where none of the cells were occluded from their view. The experimenter explained that she would play a director’s role, providing a total of 16 different instructions to move an object to a different cell in the cupboard and the participant was told to follow the instruction provided from the director (Table 1). The instructions followed a pattern of "Move the…" + the target object noun (e.g., ball, shoe, truck) + a direction (up, down, left, or right), based on the instructions used by Keysar et al. (2000).

The experimenter provided the following verbal instruction:

"*Now, we are moving onto the next task, the visuospatial experiment. For this visuospatial task, I am going to be a director who will simply give you some directions to move an object around in the cupboard, which is covered from our view at this point. This is because my research assistant has already set this up, so I have no knowledge on the details of the set-up. I am just going to give you some directions from my perspective (pointing to where I stand at the other side of the cupboard, which is still draped) and all you need to do in this experiment is to follow what I say*."

After receiving acknowledgement from the participant, the experimenter proceeded to the practical demonstration as described below. The experimenter started giving directions as follows:

“*Now, you can remove the drape and put it under the desk. As you can see, different objects are placed randomly in the cells. Please notice that some cells are occluded from my perspective, so I can see all the objects placed in the open cells, but not the ones in the occluded cells*."

Next, the experimenter asked the participant to come to her side to experience the experimenter’s (the director’s) view, then the participant returned to their original seat on the non-occluded side. Then, the experimenter (the director) gave an instruction for the purpose of giving the participant an idea of how the task worked. The instruction was as follows:

> *As I said earlier, all I am going to do is to give you some directions and you need to follow what I say. So, now we can try some practical trials, "move the Rubik's cube to the next cell on your right*." [After the participant moved the object correctly] "*Good, now move the bunny one cell down.*" [After the participant responded], "*Good, the directions will be something like that, asking you to move an object to a different cell on the cupboard*."

After the practical trial, the participant was asked to open an envelope titled "Picture 1" and to place all the items in the cupboard exactly as shown in the picture. This ensured their knowledge of the objects and their locations (i.e., placed in an occluded or open cell). During this process, the experimenter wore a blindfold to convince the participant that she had no knowledge of the locations of the objects. This process was repeated for the remaining three blocks of test trials. Once the participants finished placing all the objects in the cupboard, the first block of trials began. Instructions were administered in a similar manner as demonstrated in the practical demonstration (a full list of the objects used and sequences of the test trials can be found in Table 1). Upon completion of all the trials, the participant finished the experiment, and the experimenter thanked them for their participation.

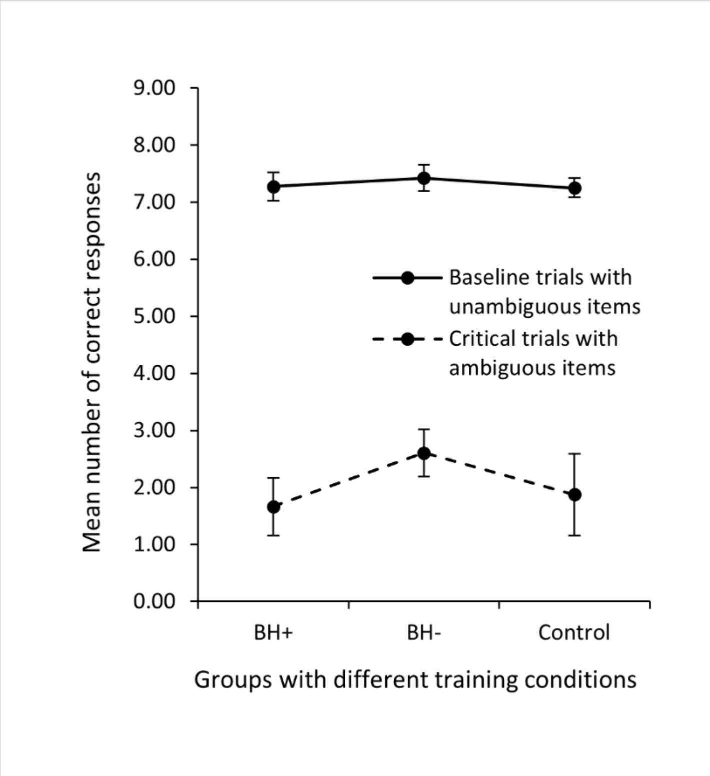
Results

Cupboard Visuospatial Perspective-taking Experiment

For the analysis of the performance results from the cupboard visuospatial perspective-taking task, we conducted a mixed ANOVA on the number of correct trials with critical items or baseline items as a within-subjects factor and the three groups (BH+, BH–, and Control) as a between-subjects factor. SPSS (https://www.ibm.com/analytics/spss-statistics-software) was used for all analyses. The assumption for homogeneity of variance was met, $F(2, 95) = 1.42$, $p = .26$. As the within-subject factors had only two levels, corrections were not needed. There was a significant effect of trial type, $F(1, 95) = 883.24$, $p < .001$, $\eta_p^2 = .9$, indicating that participants performed better on baseline trials with unambiguous items than on the critical trials with ambiguous items (Figure 2). There was no significant interaction between the performance on the trial types for the three groups, $F(2, 95) = 1.76$, $p = .18$, $\eta_p^2 = .04$. However, there was a significant main effect of group, $F(1, 95) = 3.62$, $p = .031$, $\eta_p^2 = .07$. Bonferroni-corrected pairwise comparisons for the main group effect indicated that there were significant differences (p = .04) between the BH+ and BH– groups, but not between the Control group and the BH+ (p = 1) or the BH– groups (p = .12) for the critical trials.

Figure 2

Mean Number of Correct Responses across Three Groups in the Cupboard Task



Note. The maximum number of correct responses that a participant could obtain was eight for each trial type. There was a total of eight trials per block of testing with either ambiguous or unambiguous items. Error bars indicate the 95% confidence intervals.

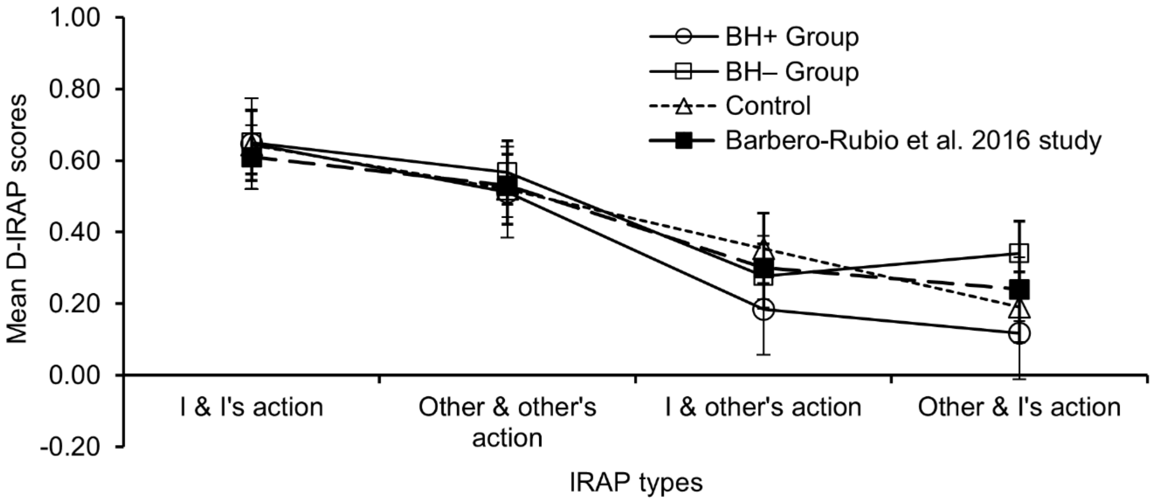
Implicit Relational Assessment Procedure Perspective-taking Experiment

An analysis of the IRAP block-sequence order effect between the D-IRAP scores of the group of 45 participants who were exposed to the *I vs. I & Other vs. Other* trial first (i.e., the participants who were required to answer as if *you were you and Tokiko were Tokiko*), M = .60, 95% CI [.49, .71], and the group of remaining 45 participants who were exposed to inconsistent trials first (i.e., answering as if *you were Tokiko and Tokiko were you*), M = .66, 95% CI [.56, .75], showed no significant effect of order on D-IRAP scores, $t(88) = -.74$, $p = .45$. Levene's test indicated equal variances ($F = 1.07$, $p = .3$).

As indicated in Figure 3, the mean D-IRAP scores from the three groups showed a strong pro-self IRAP effect in all four trial types because the D-IRAP scores were all positive (i.e., participants gave faster and more accurate responses to the consistent trials with I vs. I's action and Other vs. Others' action, compared to the inconsistent trials with I vs. Other's action and Other vs. I's action). We conducted a mixed ANOVA to evaluate the influence of the different training conditions assigned to each group on D-IRAP scores in all four trial types. There was no significant difference in D-IRAP scores among the three groups, $F(1,2) = 1.98$, $p = .14$, $\eta_p^2 = .04$. The assumption of sphericity was met, based on Mauchly's Test, $X^2(5) = 4.78$, $p = .45$.

Figure 3

D-IRAP Scores in Each Group Compared to Barbero-Rubio et al.'s (2016) Result



Note. Mean D-IRAP scores above zero indicate the participants' attitude inclined towards a pro-self-perspective (egocentric attitude), and scores below zero indicate a pro-other-perspective (faster in thinking about other's points of view rather than one's own). A score close to zero indicates that the individual is neutral and unbiased towards either of the two attitudes indicated by the pro-self and pro-other trials. The error bars indicate the 95% confidence interval.

In terms of the RPM test, the scores were equivalent among the three groups ($M = 52$). The RPM scores and number of correct responses in the visual cupboard perspective-taking task were moderately and significantly related, $r(98) = .34$, $p < .001$. There was no significant relationship between responses on the cupboard task or the four trial types of IRAP measures, $r(97) = -.007$, p

= .95 (I vs. I's action), $r(97) = -.06$, $p = .59$ (I vs. Other's action), $r(97) = -.07$, $p = .51$ (Other vs. I's action), and $r(97) = -.09$, $p = .36$ (Other vs. Other's action). There were also no significant correlations between the RPM scores and each of the four trial types of IRAP measures; $r(97)= -.04$, $p = .68$ (I vs. I's action), $r(97)= -.04$, $p = .73$ (I vs. Other's action), $r(97) = -.01$, $p = .89$ (Other vs. I's action), and $r(97) = -.09$, $p = .4$ (Other vs. Other's action).

Discussion

To test the hypothesis of whether or not deictic expressions are effective in producing general perspective-taking improvements, we examined whether accuracy in responding to the BH protocol had any influence on participants' perspective-taking ability. Effectiveness of the deictic expressions would have been evidenced in a higher response accuracy relative to the control group on the visuo-spatial cupboard task or the IRAP. To support the idea that deictic relational framing serves as a core component of perspective taking, the BH+ group alone (or both BH+ and BH– groups, if the proposition that deictic words can be replaced with specific nouns is correct) should have performed better than the control group in the two experimental perspective-taking tasks. Overall, no significant difference in perspective-taking ability, compared to the control group, was observed in the results of the two experimental groups in the two tasks.

In terms of the cupboard visuospatial task, the main finding was that the BH+ group did not show any difference in response accuracy compared to the control group's performance on critical trials with the ambiguous items. There was a main effect in the group performance, showing a difference between BH+ and BH– groups for the critical-item trials, with participants in the BH– group performing better than those in the BH+ group. Overall, however, the performance of each experimental group was not significantly different from the control group's result. Therefore, we failed to reject the null hypothesis, and concluded that there was insufficient evidence to support the alternative hypothesis that neither the deictic expressions, specific nouns, nor any other relational framing that was part of the BH protocol (e.g., 'if…then' causal relational framing) had an effect on performance in the perspective-taking tasks. Interestingly, our findings aligned with the outcome of previous studies demonstrating that verbally competent adults (i.e., university students) made substantial errors during the critical trials in the cupboard task testing the participants' ability to derive what object could be seen from another's point of view (De Lillo & Ferguson, 2022; Epley & Caruso, 2018; Keysar et al., 2003; Samson et al., 2010). Despite the fact that the adult participants knew that the director could not see some of the objects on the cupboard, some of the participants selected the object that was not mutually visible. To do well in the cupboard visual perspective-taking task, the response should be controlled by a discriminative stimulus, which is often referenced as a perceptual common ground between an interlocutor and a listener (Clark & Marshall, 1981; Keysar, 1997), and is manipulated by the presence or absence of the stimuli that block one's view of an object or an event. The ability to discriminate the perceptual common ground between self and others does not appear to be facilitated by the BH protocol.

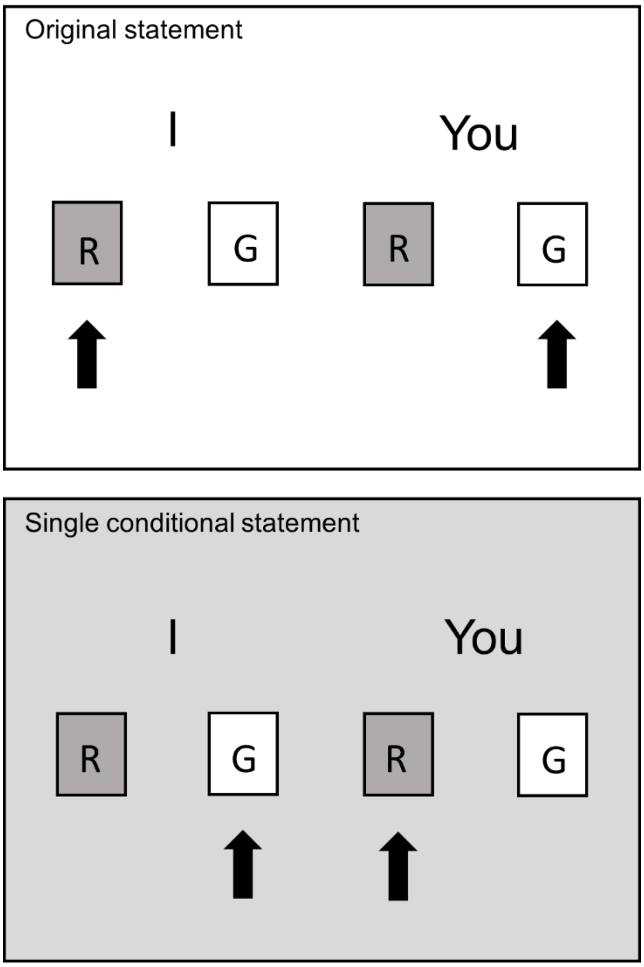
The main finding from the IRAP experiment was that there was no evidence to support the hypothesis that the 3-day period of training with the BH protocol had an effect on the IRAP performance results. Proficiency in perspective taking was measured by the participant's ability to demonstrate their indifference to the arranged dichotomy between the pro-self-perspective (i.e., responding faster in consistent trials, when answering as if "I am me, others are others") and pro-other-perspective (i.e., responding faster in inconsistent trials when answering as if "I am another, another is me"). If the IRAP score is at or close to zero, it is indicative of indifference to the two biases. However, the D-IRAP scores of our participants were consistent with those obtained by Barbero-Rubio et al. (2016), demonstrating a strong "pro-self" bias. Barbero-Rubio et al. suggested that this "pro-self" bias is the result of people being more often exposed to situations that require self-centered perspective in daily life, and also due to the immediacy of private events that are only available to individuals.

Deictic framing may lack the universality required to engage in successful perspective taking in different contexts, but it may generalize to situations with a similar format to the original BH protocol. Indeed, experiments have shown successful generalization of deictic relational responding when the test items were similar to the training items (e.g., participants were provided with tasks involving *if-then* framing, in the form of verbal questions in both training and testing; Davlin et al., 2011; Heagle & Rehfeldt, 2006; Giloy et al., 2015; Montoya-Rodríguez et al., 2017). Skills gained from the BH protocol, however, do not appear to generalize to other perspective-taking tasks.

One of the most important requirements of the BH protocol is the requirement to produce a response that corresponds with either an *initial statement* or the reverse of that statement, dependent upon the wording of a *conditional statement*. For example, following the initial statement, “I am in a green chair, and you are in a red chair,” and the conditional statement, “If I were you and you were me, where would I be?” a response that corresponds with the reverse of the original statement is reinforced (i.e., “in a red chair”). With the same initial statement but the absence of a conditional statement (only “where am I?”), participants can simply respond to what is expressed on the initial statement (Figure 4). Similarly, with questions involving a double conditional statement such as “if you were me and I were you, and if here was there and there was here” a response that corresponds with the first part of the conditional statement is sufficient to provide a correct response. The only conditional statement that requires a reversed response is the single-reversal statement. In fact, the demonstration of faster acquisition of tasks involving double conditional statements compared to single conditional ones has been observed and discussed in the literature (Heagle & Rehfeldt, 2006; Rehfeldt et al., 2007; Weil et al., 2011). This might be due to a training effect, since the most complex version of the question (double reversed) is usually provided last. However, it may also be indicative of the participants’ reliance upon simple discriminative stimuli, such as the length of the conditional statement (which is the longest in the case of double-reversals) to complete the tasks accurately (Taylor & Edwards, 2021). If participants do come to rely on such strategies to solve the BH protocol tasks then, at face value, this type of behavior appears to have very little to do with what can meaningfully be described as perspective taking.

Figure 4

Arrays of Both Sample and Comparison Stimuli in the BH Protocol in a Conditional Discrimination Task



Note. The top figure represents a simple relation task such as "I have a red brick and you have a green brick. Which brick do I have? Which brick do you have?" The correct responses are indicated by the black arrows. "R" indicates the color red, and "G" indicates green. The bottom figure represents a reversed relation task such as "I have a red brick and you have a green brick. If I were you and you were me, which brick would I have? Which brick would you have?" The background color can be arranged to serve as a conditional stimulus, as an alternative to the absence or presence of the phrase "If I were you and you were me." The grey background color indicates the single conditional statement would signal reinforcement for a response that corresponds with the reverse of the original statement. A response to the original condition would be reinforced in the presence of the white background.

There are some limitations to our study. We did not conduct a preliminary investigation to determine an appropriate duration of training for adult participants that would have allowed them to gain the optimum benefit from their exposure to the BH protocol. Each participant was exposed for less than 15 minutes per day (i.e., the daily requirement, repeated for three days, was to complete *at* *least* one task containing 15 question items), over a 3-day period. Even though the mastery criterion was set at 90% correct responses in less than 5 minutes and participants had to repeat until they passed the criterion, this type of arbitrarily constructed criterion may not have resulted in participants achieving maximum proficiency with the protocol. Another limitation was that the instructions provided during the cupboard visual perspective-taking task were originally designed to measure eye movement at the onset of the verbalization of the target object name (for example, the "g" sound in the target object name "glasses"), rather than solely overt behavioral measures (i.e., the number of correct responses per participant, of those whose hand reached out to the target object in the cupboard). Since we did not use an eye-tracking device, we did not collect duration records to compare how long it took for participants to identify the target object, as was done in previous studies (Keysar et al., 2000; Keysar et al., 2003). To measure response accuracy, the instructions could have been much simpler (e.g., directions to move the target object could have been omitted from the instruction; for example, we could have simply asked "can you give me the glasses please?"). Moreover, our participants' general use of various object names was not subject to preliminary examination. A preliminary session of one-to-one matching of the names and the objects used in the experiment may be necessary, especially when the participants are university students who have different cultural backgrounds. For example, one of the pairs of ambiguous nouns, hair pin and safety pin, was confusing for some of our participants as they were more familiar with calling a hair pin a bobby pin, so they took longer to find the intended object.

Conclusion

In light of the current findings, we question not only the validity of the theory of deictic framing and the utility of the BH protocol, but also suggest that previous approaches for investigating perspective taking may need to be re-examined. We showed that participants' fluent performance with the BH protocol task was not associated with enhanced accuracy on the other types of perspective-taking tasks: the cupboard visual perspective taking task and a perspective-taking IRAP task. It appears that changes in behavior brought about by BH protocol training can only be observed under conditions that are extremely similar to the BH protocol itself, which casts doubt upon the proposition that the protocol is relevant to behavioral processes that are fundamental to perspective taking more broadly. Going beyond these potential issues with the BH protocol, there also appear to be construct validity issues associated with the tasks designed to measure perspective-taking skills, due in part to perspective taking being a poorly defined social construct. Researchers need to develop a more systematic approach to identifying the specific stimulus functions of relevant stimuli in instances of successful perspective taking, and work to understand how these functions can be established. Such an approach, in our view, would be more effective than passive “train and hope” approaches (Stokes & Baer, 1977, p. 351). Stokes and Baer (1977) warn that the absence of a program of generalization for various behavioral interventions is a problem. This concern remains significant in relation to our approaches to examining the generalization of acquired perspective-taking abilities from various training and testing schemes.

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Appendix A

Deictic Framing Protocol (adapted from McHugh, et al., 2004a study) 60 Questions total

Simple Relations

Simple I-You

I have a red brick and you have a green brick.
Which brick do I have?
Which brick do YOU have?

I have a green brick and you have a red brick.
Which brick do YOU have?
Which brick do I have?

Simple HERE-THERE

I am sitting here on the blue chair and you are sitting there on the black chair.
Where am I sitting?
Where are YOU siting?

I am sitting here on the black chair and you are sitting there on the blue chair.
Where are YOU sitting?
Where am I sitting?

Simple NOW-THEN

Yesterday I was watching television, today I am reading.
What am I doing now?
What was I doing then?

Yesterday I was reading, today I am watching television.
What was I doing then?
What am I doing now?

Yesterday you were reading, today you are watching television.
What are YOU doing now?
What were YOU doing then?

Yesterday you were watching television, today you are reading.
What were YOU doing then?
What are YOU doing now?

REVERSED RELATIONS

Reversed I-YOU

I have a red brick and you have a green brick. If I was you and you were me,
Which brick would I have?
Which brick would YOU have?

I have a green brick and you have a red brick. If I was you and you were me,
Which brick would YOU have?
Which brick would I have?

I have a red brick and you have a green brick. If I was you and you were me,
Which brick would YOU have?
Which brick would I have?

I have a green brick and you have a red brick. If I was you and you were me,
Which brick would I have?
Which brick would YOU have?

I am sitting here on the black chair and you are sitting there on the blue chair. If I was you and you were me,
Where would YOU be sitting?
Where would I be sitting?

I am sitting here on the black chair and you are sitting there on the blue chair. If I was you and you were me,
Where would I be sitting?
Where would YOU be sitting?

I am sitting here on the blue chair and you are sitting there on the black chair. If I was you and you were me,
Where would I be sitting?
Where would YOU be sitting?

I am sitting here on the blue chair and you are sitting there on the black chair. If I was you and you were me,
Where would YOU be sitting?
Where would I be sitting?

Reversed HERE-THERE

I am sitting here on the blue chair and you are sitting there on the black chair. If here was there and there was here,
Where would YOU be sitting?
Where would I be sitting?

I am sitting here on the black chair and you are sitting there on the blue chair. If here was there and there was here,
Where would I be sitting?
Where would YOU be sitting?

I am sitting here on the blue chair and you are sitting there on the black chair. If here was there and there was here,
Where would I be sitting?
Where would YOU be sitting?

I am sitting here on the black chair and you are sitting there on the blue chair. If here was there and there was here,
Where would YOU be sitting?
Where would I be sitting?

Yesterday, I was sitting there on the blue chair, today I am sitting here on the black chair. If here was there and there was here,
Where would I be sitting now?

Where was I sitting then?

Yesterday, I was sitting there on the black chair, today I am sitting here on the blue chair. If here was there and there was here,
Where was I sitting then?
Where would I be sitting now?

Yesterday, I was sitting there on the blue chair, today I am sitting here on the black chair. If here was there and there was here,
Where was I sitting then?
Where would I be sitting now?

Yesterday, I was sitting there on the black chair, today I am sitting here on the blue chair. If here was there and there was here,
Where would I be sitting now?
Where was I sitting then?

Yesterday, you were sitting there on the blue chair, today You are sitting here on the black chair. If here was there and there was here,
Where would you be sitting now?
Where were you sitting then?

Yesterday, you were sitting there on the blue chair, today You are sitting here on the black chair. If here was there and there was here,
Where were you sitting then?
Where would you be sitting now?

Yesterday, you were sitting there on the black chair, today You are sitting here on the blue chair. If here was there and there was here,
Where would you be sitting now?
Where were you sitting then?

Yesterday, you were sitting there on the black chair, today You are sitting here on the blue chair. If here was there and there was here,
Where were you sitting then?
Where would you be sitting now?

Reversed NOW-THEN:

Yesterday I was watching television, today I am reading. If now was then and then was now,
What was I doing then?
What would I be doing now?

Yesterday I was watching television, today I am reading. If now was then and then was now,
What was I doing then?
What would I be doing now?

Yesterday I was reading, today I am watching television. If now was then and then was now,
What would I be doing now?
What was I doing then?

Yesterday I was watching television, today I am reading. If now was then and then was now,
What would I be doing now?
What was I doing then?

Yesterday I was reading, today I am watching television. If now was then and then was now,
What was I doing then?
What would I be doing now?

Yesterday you were watching television, today you are reading. If now was then and then was now,
What were you doing then?
What would you be doing now?

Yesterday you were reading, today you are watching television. If now was then and then was now,
What were you be doing then?
What would you be doing now?

Yesterday you were watching television, today you are reading. If now was then and then was now,
What would you be doing now?
What were you doing then?

Yesterday you were reading, today you are watching television. If now was then and then was now,
What would you be doing now?
What were you doing then?

Yesterday I was sitting there on the blue chair, today I am sitting here on the black chair. If now was then and then was now.
Where would I be sitting now?
Where was I sitting then?

Yesterday I was sitting there on the blue chair, today I am sitting here on the black chair. If now was then and then was now.
Where was I sitting then?
Where would I be sitting now?

Yesterday I was sitting there on the black chair, today I am sitting here on the blue chair. If now was then and then was now.
Where would I be sitting now?
Where was I sitting then?

Yesterday I was sitting there on the black chair, today I am sitting here on the blue chair. If now was then and then was now.
Where was I sitting then?
Where would I be sitting now?

Yesterday you were sitting there on the blue chair, today you are sitting here on the black chair. If now was then and then was now.
Where were you sitting then?
Where would you be sitting now?

Yesterday you were sitting there on the blue chair, today you are sitting here on the black chair. If now was then and then was now.
Where would you be sitting now?
Where were you sitting then?

Yesterday you were sitting there on the black chair, today you are sitting here on the blue chair. If now was then and then was now.
Where were you sitting then?
Where would you be sitting now?

Yesterday you were sitting there on the black chair, today you are sitting here on the blue chair. If now was then and then was now.
Where would you be sitting now?
Where were you sitting then?

DOUBLE REVERSED RELATIONS

I-YOU/HERE-THERE:

I am sitting here on the blue chair and you are sitting there on the black chair. If I was you and you were me and if here was there and there was here,
Where would I be sitting?
Where would YOU be sitting?

I am sitting here on the blue chair and you are sitting there on the black chair. If I was you and you were me and if here was there and there was here,
Where would YOU be sitting?
Where would I be sitting?

I am sitting here on the black chair and you are sitting there on the blue chair. If I was you and you were me and if here was there and there was here,
Where would I be sitting?
Where would YOU be sitting?

I am sitting here on the blue chair and you are sitting there on the black chair. If I was you and you were me and if here was there and there was here,
Where would YOU be sitting?
Where would I be sitting?

I am sitting here on the black chair and you are sitting there on the blue chair. If I was you and you were me and if here was there and there was here,
Where would YOU be sitting?
Where would I be sitting?

I am sitting here on the black chair and you are sitting there on the blue chair. If I was you and you were me and if here was there and there was here,
Where would YOU be sitting?
Where would I be sitting?

HERE-THERE / NOW-THEN

Yesterday I was sitting there on the blue chair, today I am sitting here on the black chair. If here was there and there was here and if now was then and then was now,
Where would I be sitting then?
Where would I be sitting now?

Yesterday I was sitting there on the blue chair, today I am sitting here on the black chair. If here was there and there was here and if now was then and then was now,
Where would I be sitting now?
Where would I be sitting then?

Yesterday I was sitting there on the black chair, today I am sitting here on the blue chair. If here was there and there was here and if now was then and then was now,
Where would I be sitting then?
Where would I be sitting now?

Yesterday I was sitting there on the black chair, today I am sitting here on the blue chair. If here was there and there was here and if now was then and then was now,
Where would I be sitting now?
Where would I be sitting then?

Yesterday you were sitting there on the blue chair, today you are sitting here on the black chair. If here was there and there was here and if now was then and then was now,
Where would YOU be sitting then?
Where would YOU be sitting now?

Yesterday you were sitting there on the blue chair, today you are sitting here on the black chair. If here was there and there was here and if now was then and then was now,
Where would YOU be sitting now?
Where would YOU be sitting then?

Yesterday you were sitting there on the black chair, today you are sitting here on the blue chair. If here was there and there was here and if now was then and then was now,
Where would YOU be sitting then?
Where would YOU be sitting now?

Yesterday you were sitting there on the black chair, today you are sitting here on the blue chair. If here was there and there was here and if now was then and then was now,
Where would YOU be sitting now?
Where would YOU be sitting then?

Appendix B

Non-Deictic Component Protocol 60 questions Total

SIMPLE RELATIONS

Simple X - Y
X has a red brick and Y has a green brick.
Which brick does X have?
Which brick does Y have?

X has a green brick and Y has a red brick.
Which brick does Y have?
Which brick does X have?

Simple location

X is sitting on the blue chair and Y is sitting on the black chair.
Where is X sitting?
Where is Y siting?

X is sitting on the black chair and Y is sitting on the blue chair.
Where is Y sitting?
Where is X sitting?

Simple Monday and Wednesday

Monday X is watching television, Wednesday X is reading.
What is X doing on Wednesday?
What is X doing on Monday?

Monday X is reading, Wednesday X is watching television.
What is X doing on Monday?
What is X doing on Wednesday?

Monday Y is reading, Wednesday Y is watching television.
What is Y doing on Wednesday?
What is Y doing on Monday?

Monday Y is watching television, Wednesday Y is reading.
What is Y doing on Monday?
What is Y doing on Wednesday?

REVERSED RELATIONS

Reversed X – Y

X has a red brick and Y has a green brick. If X was Y and Y was X,
Which brick would X have?
Which brick would Y have?

X has a green brick and Y has a red brick. If X was Y and Y was X,
Which brick would Y have?
Which brick would X have?

X has a red brick and Y has a green brick. If X was Y and Y was X,
Which brick would Y have?
Which brick would X have?

X has a green brick and Y has a red brick. If X was Y and Y was X,
Which brick would X have?
Which brick would Y have?

X is sitting on the black chair and Y is sitting there on the blue chair. If X was Y and Y was X,
Where would Y be sitting?
Where would X be sitting?

X is sitting on the black chair and Y is sitting on the blue chair. If X was Y and Y was X,
Where would X be sitting?
Where would Y be sitting?

X am sitting on blue chair and Y is sitting on the black chair. If X was Y and Y was X,
Where would X be sitting?
Where would Y be sitting?

X is sitting on the blue chair and Y is sitting on the black chair. If X was Y and Y was X,
Where would Y be sitting?
Where would X be sitting?

Reversed location

X is sitting on the blue chair and Y is sitting on the black chair. If the blue chair was the black chair and the black chair was the blue chair,
Where would Y be sitting?
Where would X be sitting?

X is sitting on the black chair and Y is sitting on the blue chair. If the blue chair was the black chair and the black chair was the blue chair,
Where would X be sitting?
Where would Y be sitting?

X is sitting on the blue chair and Y is sitting on the black chair. If the blue chair was the black chair and the black chair was the blue chair,
Where would X be sitting?
Where would Y be sitting?

X is sitting on the black chair and Y is sitting on the blue chair. If the blue chair was the black chair and the black chair was the blue chair,
Where would Y be sitting?
Where would X be sitting?

Monday, X is sitting on the blue chair, Wednesday X is sitting on the black chair. If the blue chair was the black chair and the black chair was the blue chair,
Where is X sitting on Wednesday?
Where is X sitting on Monday?

Monday, X is sitting on the black chair, Wednesday X is sitting on the blue chair. If the blue chair was the black chair and the black chair was the blue chair,
Where is X sitting on Monday?
Where is X sitting Wednesday?

Monday, X is sitting on the blue chair, Wednesday X is sitting on the black chair. If the blue chair was the black chair and the black chair was the blue chair,
Where is X sitting on Monday?
Where is X sitting on Wednesday?

Monday, X is sitting on the black chair, Wednesday X is sitting on the blue chair. If the blue chair was the black chair and the black chair was the blue chair,
Where is X sitting on Wednesday?
Where is X sitting on Monday?

Monday, Y is sitting on the blue chair, Wednesday Y is sitting on the black chair. If the blue chair was the black chair and the black chair was the blue chair,
Where is Y sitting on Wednesday?
Where is Y sitting on Monday?

Monday, Y is sitting on the blue chair, Wednesday Y is sitting on the black chair. If the blue chair was the black chair and the black chair was the blue chair,
Where is Y sitting on Monday?
Where is Y sitting on Wednesday?

Monday, Y is sitting on the black chair, Wednesday Y is sitting on the blue chair. If the blue chair was the black chair and the black chair was the blue chair,
Where is Y sitting on Wednesday?
Where is Y sitting on Monday?

Monday, Y is sitting on the black chair, Wednesday Y is sitting on the blue chair. If the blue chair was the black chair and the black chair was the blue chair,
Where is Y sitting on Monday?
Where is Y sitting on Wednesday?

Reversed Monday - Wednesday

Monday X is watching television, Wednesday X is reading. If Wednesday was Monday and Monday was Wednesday,
What is X doing on Monday?
What is X doing on Wednesday?

Monday X is watching television, Wednesday X is reading. If Wednesday was Monday and Monday was Wednesday,
What is X doing on Monday?
What is X doing on Wednesday?

Monday X is reading, Wednesday X is watching television. If Wednesday was Monday and Monday was Wednesday,
What is X doing on Wednesday?
What is X doing on Monday?

Monday X is watching television, Wednesday X is reading. If Wednesday was Monday and Monday was Wednesday,
What is X doing on Wednesday?
What is X doing on Monday?

Monday X is reading, Wednesday X is watching television. If Wednesday was Monday and Monday was Wednesday,

What is X doing on Monday?
What is X doing on Wednesday?

Monday Y is watching television, Wednesday Y is reading. If Wednesday was Monday and Monday was Wednesday,
What is Y doing on Monday?
What is Y doing on Wednesday?

Monday Y is reading, Wednesday Y is watching television. If Wednesday was Monday and Monday was Wednesday,
What is Y doing on Monday?
What is Y doing on Wednesday?

Monday Y is watching television, Wednesday Y is reading. If Wednesday was Monday and Monday was Wednesday,
What is Y doing on Wednesday?
What is Y doing on Monday?

Monday Y is reading, Wednesday Y is watching television. If Wednesday was Monday and Monday was Wednesday,
What is Y doing on Wednesday?
What is Y doing on Monday?

Monday X is sitting on the blue chair, Wednesday X is sitting on the black chair. If Wednesday was Monday and Monday was Wednesday,
Where is X sitting on Wednesday?
Where is X sitting on Monday?

Monday X is sitting on the blue chair, Wednesday X is sitting on the black chair. If Wednesday was Monday and Monday was Wednesday,
Where is X sitting on Monday?
Where is X sitting on Wednesday?

Monday X is sitting on the black chair, Wednesday X is sitting on the blue chair. If Wednesday was Monday and Monday was Wednesday,
Where is X sitting on Wednesday?
Where is X sitting on Monday?

Monday X is sitting on the black chair, Wednesday X is sitting on the blue chair. If Wednesday was Monday and Monday was Wednesday,
Where is X sitting on Monday?
Where is X sitting on Wednesday?

Monday Y is sitting on the blue chair, Wednesday Y is sitting on the black chair. If Wednesday was Monday and Monday was Wednesday,
Where is Y sitting on Monday?
Where is Y sitting on Wednesday?

Monday Y is sitting on the blue chair, Wednesday Y is sitting on the black chair. If Wednesday was Monday and Monday was Wednesday,
Where would Y be sitting on Wednesday?
Where was Y sitting on Monday?

Monday Y was sitting on the black chair, Wednesday Y is sitting on the blue chair. If Wednesday was Monday and Monday was Wednesday,

Where is Y sitting on Monday?
Where is Y sitting on Wednesday?

Monday Y is sitting on the black chair, Wednesday Y is sitting on the blue chair. If Wednesday was Monday and Monday was Wednesday,
Where is Y sitting on Wednesday?
Where is Y sitting on Monday?

DOUBLE REVERSED RELATIONS

X – Y / location

X is sitting on the blue chair and Y is sitting on the black chair. If X was Y and Y was X and if the blue chair was the black chair and the black chair was the blue chair,
Where would X be sitting?
Where would Y be sitting?

X is sitting on the blue chair and Y is sitting on the black chair. If X was Y and Y was X and if the blue chair was the black chair and the black chair was the blue chair,
Where would Y be sitting?
Where would X be sitting?

X is sitting on the black chair and Y is sitting on the blue chair. If X was Y and Y was X and if the blue chair was the black chair and the black chair was the blue chair,
Where would X be sitting?
Where would Y be sitting?

X is sitting on the blue chair and Y is sitting on the black chair. If X was Y and Y was X and if the blue chair was the black chair and the black chair was the blue chair,
Where would Y be sitting?
Where would X be sitting?

X is sitting on the black chair and Y is sitting on the blue chair If X was Y and Y was X and if the blue chair was the black chair and the black chair was the blue chair,
Where would Y be sitting?
Where would X be sitting?

X is sitting on the black chair and Y is sitting on the blue chair. If X was Y and Y was X and if the blue chair was the black chair and the black chair was the blue chair,
Where would Y be sitting?
Where would X be sitting?

Location / Monday - Wednesday

Monday X is sitting on the blue chair, Wednesday X is sitting on the black chair. If the blue chair was the black chair and the black chair was the blue chair and if Wednesday was Monday and Monday was Wednesday,
Where would X be sitting on Monday?
Where would X be sitting on Wednesday?

Monday X is sitting on the blue chair, Wednesday X is sitting on the black chair. If the blue chair was the black chair and the black chair was the blue chair and if Wednesday was Monday and Monday was Wednesday,
Where would X be sitting on Wednesday?
Where would X be sitting on Monday?

Monday X is sitting on the black chair, Wednesday X is sitting on the blue chair. If the blue chair was the black chair and the black chair was the blue chair and if Wednesday was Monday and Monday was Wednesday,
Where would X be sitting on Monday?
Where would X be sitting on Wednesday?

Monday X is sitting on the black chair, Wednesday X is sitting on the blue chair. If the blue chair was the black chair and the black chair was the blue chair and if Wednesday was Monday and Monday was Wednesday,
Where would X be sitting on Wednesday?
Where would X be sitting on Monday?

Monday Y is sitting on the blue chair, Wednesday Y is sitting on the black chair. If the blue chair was the black chair and the black chair was the blue chair and if Wednesday was Monday and Monday was Wednesday,
Where would Y be sitting on Monday?
Where would Y be sitting on Wednesday?

Monday Y is sitting on the blue chair, Wednesday Y is sitting on the black chair. If the blue chair was the black chair and the black chair was the blue chair and if Wednesday was Monday and Monday was Wednesday,
Where would Y be sitting on Wednesday?
Where would Y be sitting on Monday?

Monday Y is sitting on the black chair, Wednesday Y is sitting on the blue chair. If the blue chair was the black chair and the black chair was the blue chair and if Wednesday was Monday and Monday was Wednesday,
Where would Y be sitting on Monday?
Where would Y be sitting on Wednesday?

Monday Y is sitting on the black chair, Wednesday Y is sitting on the blue chair. If the blue chair was the black chair and the black chair was the blue chair and if Wednesday was Monday and Monday was Wednesday,
Where would Y be sitting on Wednesday?
Where would Y be sitting on Monday?

Appendix C

Deictic Reading Comprehension Tasks 60 Items

I have a red brick and you have a green brick.

I have a green brick and you have a red brick.

I am sitting here on the blue chair and you are sitting there on the black chair.

I am sitting here on the black chair and you are sitting there on the blue chair.

Yesterday I was watching television, today I am reading.

Yesterday I was reading, today I am watching television.

Yesterday you were reading, today you are watching television.

Yesterday you were watching television, today you are reading.

I have a red brick and you have a green brick.

I have a green brick and you have a red brick.

I am sitting here on the black chair and you are sitting there on the blue chair.

I am sitting here on the blue chair and you are sitting there on the black chair.

Yesterday, I was sitting there on the blue chair, today I am sitting here on the black chair

Yesterday, I was sitting there on the black chair, today I am sitting here on the blue chair.

Yesterday I was watching television, today I am reading.

Yesterday I was reading, today I am watching television.

Yesterday you were watching television, today you are reading.

Yesterday you were reading, today you are watching television

I have an orange pencil and you have a yellow pencil.

I have a yellow pencil and you have an orange pencil.

I am sitting here on the pink couch and you are sitting there on the purple couch.

I am sitting here on the purple couch and you are sitting here on the pink couch.

Yesterday, I was playing video games, today I am listening to music.

Yesterday I was listening to music, today I am playing video games.

Yesterday you were listening to music, today you are playing video games.

Yesterday you were playing video games, today you are listening to music.

Yesterday I was sitting there on the pink couch, today I am sitting here on the purple couch.

Yesterday I was sitting there on the pink couch, and today I am sitting here on the pink couch.

Yesterday you were sitting there on the pink couch, today you are sitting here on the purple couch.

Yesterday you were sitting there on the pink couch, and today you are sitting here on the pink couch.

I have the hamburger and you have the grilled cheese.

You have the hamburger and I have the grilled cheese.

I am standing in the classroom and you are standing on the playground.

You are standing in the classroom, and I am standing on the playground.

Yesterday I was playing X-Box, today I am watching “The Incredible”

Yesterday you were watching “The Incredible,” today I am playing X-box.

Yesterday you were reading comic books, today you are talking on the phone

Today I am talking on the phone, yesterday I was reading comic books.

I am holding the puppy and you are holding the kitten.

You are holding the puppy and I am holding the kitten.

Yesterday I was swimming there in the pool, today I am swimming here in the lake.

Today you are swimming here in the lake, yesterday you were swimming there in the pool.

Yesterday I was doing my homework; today I am taking a nap.

Yesterday you were playing soccer, today you are playing basketball.

Today I am playing soccer, yesterday I was playing basketball.

I am sleeping here in the bedroom and you are sleeping there in the living room.

You are sleeping here in the living room, and I am sleeping there in the bedroom.

I am here eating McDonalds and you are eating there at Wendy’s. You are eating here at Wendy’s and I am eating there at McDonalds.

Yesterday I was shopping there at the mall; today I am shopping there at the grocery store.

Yesterday you were running there in the park; today you are running here in gym class.

Today I am running here in the park; yesterday I was running there in gym class.

I have a book and you have a comic book.

You have a book and I have a comic book.

I am driving Honda and you are driving Toyota.

You are driving Honda, and I am driving Toyota.

Yesterday I was cooking rice, today I am cooking pasta.

Yesterday you were cooking pasta today I am cooking rice.

Yesterday you were skiing, today you are skating.

Today I am skating, yesterday I was skiing.

I own a hotel here in Hamilton and you own a house there in Queenstown.

Chapter 2

Experiment 2[1]

Evaluation of the Relational Triangulation Framework: Testing for Derivation of the Perspective of Others under the Contextual Control of Same and Opposite Stimuli

[1]Taylor, T., & Edwards, T. L. (2022). Evaluation of the relational triangulation framework: Testing for derivation of the perspective of others under the contextual control of same and opposite stimuli [Unpublished manuscript]. School of Psychology, University of Waikato.

Chapter Introduction

In the previous experiment, I investigated the utility in claiming deictic framing as a core component in perspective taking. My findings indicated that the deictic framing component appeared to have no direct effect on enhancing participants' perspective-taking skills when applied to contexts different (i.e., "distant-transfer" tasks) to the one in which the learning took place (i.e., the BH protocol). This may indicate that the stimulus functions associated with deictic framing theoretically acquired from the BH protocol may only predict the learner's accurate response when the acquired skill is applied to a context similar to that presented in the BH protocol. This context could include the use of conditional phrases (i.e., "if-then"), the length of phrases, and the form of questioning used (i.e., starting with "what"). The failure to observe the expected outcome of response generalisation raised a question about what behavioural processes are fundamental to perspective taking in a broader context. Additionally, the findings suggested that there may be conceptual issues with the BH protocol, in which deictic framing may not be a core element of perspective taking. Thus, the broader applicability of the BH protocol to perspective taking remains questionable.

The relational triangulation (RT) framework proposed by Guinther (2017, 2018) appears to provide a more solid approach to conceptualising the behavioural process involved in perspective taking within relational frame theory (RFT), which is rooted in behaviour-analytic research on human language and cognition (Gross & Fox, 2009). Guinther (2017) questioned the conceptual integrity of deictic framing and proposed the RT framework, which explains how deriving a perspective of another person is contextually controlled. The RT framework indicates that some perspective-taking scenarios can be represented by a triangle, with two sides representing the functions of a target stimulus for two individuals, and the third side indicating the "interpersonal alignment," or relationship, between the two individuals with respect to those stimulus functions (e.g., same, different, opposite). Guinther (2017) defined "perspective" as a function specified by a stimulus-response relation. This definition suggests a mechanism by which the perspectives of others can be derived. Importantly, the proposed RT framework is conceptually divergent from the account of deictic relational framing, as mentioned in the previous manuscript. Guinther's (2017, 2018) experiments provided empirical evidence to support the conceptual framework, demonstrating that deriving the perspective of others was based on a participant's relational responding involving spatio-temporal stimuli, and the functions of the relevant stimuli are derived as the designated other person's perspective through a process known as the transformation of stimulus functions. The RT conceptual framework may be a significant step forward in the pursuit of parsimony and practicality in understanding perspective taking.

Despite the empirical evidence supporting the utility of the RT framework, some aspects of the framework require further clarification. The aim of this introduction is to point out some issues that need to be clarified. Further details of the mechanism of the RT framework are discussed in the following manuscript. The first issue is that the proposed stimulus property of "sameness" remains hypothetical. In the RT framework, the triangulation of the two known sides of perspectives entailing the third was presented as the behavioural process necessary for a person to emit a derived response predicting another person's perspective. For example, if you know that Mike likes cats and Mary is the same as Mike, then you can derive Mary's fondness toward cats. If we try to plug in the above example to the framework, we can see that the perspective of Mike, who likes cats, and the stimulus property of sameness entails Mary's affection for cats. Guinther (2017) explained that this aspect of derivation was achieved by the process known as transformation of stimulus functions (i.e., the function of fondness of cats being transferred from the person stimulus, "Mike" to "Mary") through the contextual cue of *sameness*. However, one question that was not clarified in Guinther's (2017) experiment was whether the participants were contextually controlled by the stimulus property of *sameness*, or if they could have been influenced by other stimuli in the experimental context, such as common visual features. Because there was no contextual stimulus arranged as bearing the relational property of sameness in the experiment, the emergence of the interpersonal relation of sameness was assumed to have been deduced by his participants. Guinther (2017) suggested testing the assumption using a non-equivalent relation (e.g., opposition) to clarify the transformation process of the stimulus functions.

In designing my experiment, I followed Guinther's (2017) suggestions. However, I arranged the experiment entirely based on a series of conditional-discrimination procedures using arbitrary stimuli, which could further demonstrate the generality of the RT framework. In Guinther's (2017,

2018) experiments, various stimuli such as Lego figurines and other Lego bricks were used to exert spatial and positional control in both the training and testing phases. However, due to the wide range of stimulus properties associated with the experimental stimuli, the arrangement in these experiments may not be ideal for precisely determining the stimulus control exerted by the experimentally specified stimuli. The second issue that needs to be clarified with the RT framework is whether or not the spatial features are necessary for deriving another's perspective, or whether they are just one type of any number of stimuli that can serve as contextual stimuli. By focusing on the basic procedures that generate the derivation response outcomes, we can clarify what is absolutely necessary for an individual to emit an accurate derived response. This could also show how the aforementioned stimulus properties of sameness and opposition could be derived, demonstrating that relevant stimuli and derived responses can be contextually controlled through the conditional-discrimination procedure and transformation of stimulus functions.

I examined Guinther's (2017, 2018) RT model using minimal stimulus conditions by removing all the social stimuli (including spatial and positional properties) for the purpose of examining triangulation as a form of conditional discrimination. In the following manuscript, a broader applicability of the RT framework is demonstrated, and some theoretical concerns regarding relational framing of *same* and *opposite* are discussed.

Evaluation of the Relational Triangulation Framework: Testing for Derivation of the Perspective of Others under the Contextual Control of Same and Opposite Stimuli

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Abstract

Studies seeking to identify the stimulus components and functions involved in perspective taking, and how these components might be learned, are still in their infancy. The relational processes, and more generally the behavioural mechanisms involved in perspective taking and relevant experimental procedures, must be clarified before research in this area can progress. Through the relational triangulation framework, Guinther suggests that each perspective is derived through the process of relational responding, as defined by relational framing theory. Guinther produced evidence in support of this framework using contextually controlled stimuli (examining the relational frame of coordination); however, it was unclear whether the derived responses were the result of the contextual control exerted by the specific contextual stimulus of *same*, or whether the responses were influenced by other types of contextual stimuli available in the experimental context. We evaluated the utility of the framework by examining whether participants could derive the perspective of others (i.e., infer stimulus functions for another person) after exposure to a matching-to-sample procedure involving either social-stimuli (faces) or arbitrary stimuli (geometric shapes) situated in frames of coordination and opposition. We demonstrated that Guinther's relational triangulation framework can be translated directly into a standard experimental protocol, and provide further support for this model. We also raise important questions about the nature of perspective taking and the potential interactive role between the fundamental behavioural processes and the higher-order relational processes involved.

Key words: theory of mind, perspective taking, relational triangulation framework, relational frame theory

Evaluation of the Relational Triangulation Framework: Testing for Derivation of the Perspective of Others under the Contextual Control of Same and Opposite Stimuli

Perspective taking is often construed as the ability to treat other entities as intentional agents, an ability commonly referred to as "Theory of Mind" (ToM; Premack & Woodruff, 1978) or "mind-reading" (Apperly, 2011; Baron-Cohen et al., 1997). This approach to conceptualising perspective taking is problematic because the hypothetical construct, ToM, does not appear to advance our practical understanding of perspective taking; instead, it appears to be a cultural *meme* (Schlinger, 2009, 2017). Spradlin and Brady (2008) proposed a behavioural interpretation of perspective taking. They hypothesised that a critical prerequisite to perspective taking for young children is learning that the stimuli available to the self and others is sometimes different. Stimuli that are indicative of others' experiences differing from the child's own experiences come to control the child's behaviour with respect to the other person. Additionally, Spradlin and Brady, along with other researchers, have suggested that, through processes related to stimulus equivalence, there may be a "linkage" between the private events of self and of others (Greer et al., 2006; Peláez et al., 2000; Peláez, 2009; Paláez & Monlux, 2018; Spradlin & Brady, 2008). For example, a mother might say to a child who is demonstrating a certain facial expression that he is "unhappy." Then, in a different situation, the child may observe another person saying "unhappy" to someone who is crying. The common expression "unhappy" may serve to link the child's own private events related to unhappiness to the other person's "unhappy" public behaviour (Spradlin & Brady, 2008).

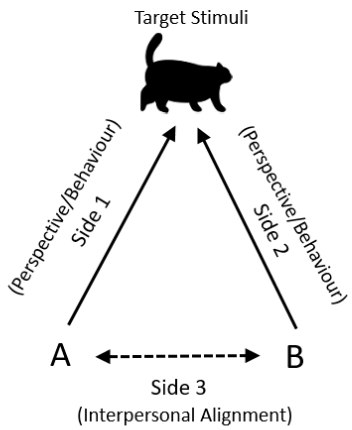
Relational Triangulation model

Guinther (2017, 2018) extended Spradlin and Brady's (2008) behavioural conceptualisation of perspective taking by applying a functional contextual approach, based on relational frame theory (RFT; Hayes et al., 2001). Guinther (2017) aimed to understand "how environmental variables can be manipulated to achieve influence over derived perspective-taking behaviour" (p. 433). Guinther developed the Relational Triangulation (RT) framework, a conceptualisation of perspective taking that appeals to RFT and behavioural principles more generally. This framework differs from another approach to perspective taking developed within RFT, the deictic framing approach, which appears to be conceptually problematic (see Guinther, 2017, 2021; Taylor & Edwards, 2021).

The RT framework indicates that some perspective-taking scenarios can be represented with a triangle, with two sides representing the functions of a target stimulus for two individuals, and the third side indicating the "interpersonal alignment," or relationship, between the two individuals with respect to those stimulus functions (e.g., same, different, opposite). Figure 1, adapted from Guinther's original figures,[2] shows an example of Relational Triangulation. The bottom corners of the triangle represent the "pointing origins" of Individuals A and B, the top corner represents a target stimulus (e.g., the cat), and the three sides of the triangle represent "bearings," which represent the stimulus functions that are relevant to the perspective-taking scenario.

Figure 1

A Simplified Diagram Created from Guinther's (2017, 2018) Original Figures



According to the RT model, any two sides entail the third. For example, one can derive Person B's perspective by knowing the bearings of Sides 1 and 3: the function of the target stimulus for Person A, and the interpersonal alignment between A and B. Guinther (2017, 2018) proposed that the derived perspective is an act of relational responding; it involves an abstraction process in which one relational network is related to another relational network, similar to analogical relational responding.

[2] The original RT framework is slightly different to the above; it involves "self" as a pointing origin in the triangle. Side 1 was described as "self-stimuli bearings", side 2 as "other-stimuli bearings," and side 3 as "self-other bearings" in the original diagram (see Guinther 2017, p. 436; 2018 p. 502). In a subsequent study, Guinther demonstrated the triangulation of another's perspective across an *Other-Other* interpersonal alignment of coordination (Guinther, 2018).

In his first study on relational triangulation, Guinther (2017) demonstrated contextual influence over deriving the true beliefs of others[3] from a known side of the triangle, such as the perspective of *self* (i.e., given the stimulus function in terms of the participant's bodily self), and an equivalence relation between the self and the other person. Using a matching-to-sample (MTS) training procedure, the participant's point of view (i.e., "self" perspective) and two Lego figure avatars were paired with unique symbols. Then, the avatars were placed around a 3-x-3 grid, while the self-perspective was represented by the viewpoint of a camera showing a scene on the computer screen. The participants were trained to make a "pointing response," by pressing a number, (from 1–9 on the 3-x-3 number pad of a computer keyboard) that corresponded with the position of a target on the grid from the "self" or the avatar's perspective (e.g., if the target appeared in the closest left-hand corner of the grid from the avatar's perspective, pressing "1" was reinforced). In some trials a "wall" was erected across the middle of the 3-x-3 grid, blocking the "view" of the farthest three spaces from the avatar. On trials in which multiple avatars were present in the scene, the correct response was dependent upon the symbol corresponding to the designated avatar's perspective. Participants were also taught to press a specific key corresponding with each of the three Lego Star Wars figures (i.e., to indicate their identity). In the final stage, under extinction conditions, participants accurately indicated the identity of the Lego Star Wars figurine that was "visible" to an avatar (i.e., located on the close side of the wall bisecting the grid), thereby providing evidence for derived "true belief" via relational triangulation. Guinther described this training process as "roughly analogous to bringing 'joint attending' and 'seeing-leads-to-knowing' repertoires under contextual control" (p. 447).

In a sequel to the first study, Guinther (2018) examined whether participants were able to correctly derive an avatar's perspective, where such derivation involved identifying that the avatar was acting based on a false-belief attribution, which demonstrated that the RT protocol also applies to the concept of "*not-seeing-leads-to-knowing*" (p. 504). After the participants completed the same

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[3] The concept of *seeing-leads-to-knowing* is considered a cornerstone of Theory of Mind (Baron-Cohen & Goodhart, 1994: Wimmer et al, 1983). An experimental task to test children's understanding of true belief is generally very simple, and is usually conducted using two dolls. There are two boxes, each containing a toy, and the dolls hold a box each. One of the dolls lifts the lid of the box and 'looks' inside, but the other doll does not. Then children are asked "Who knows what's in the box? John or Fiona?" This is the test of children's understanding of how their own or someone else's visual access equates to one's state of "knowing."

experimental procedures as in the first study (Guinther, 2017), they were then trained to indicate the target stimulus that a designated Avatar (A2) had last seen. For instance, the participants observed a series of photographed scenes showing Avatar A2 facing towards the target (e.g., a Luke Skywalker figurine). The target was then occluded from A2's view by a Lego wall placed between A2 and the target. Then, the target (Luke Skywalker), was swapped with another figurine (e.g., Obi-Wan Kenobi) without A2 being able to "see" the change. The participant's selection of Luke Skywalker (i.e., pressing C key on the keyboard) was reinforced as demonstrating their understanding of false-belief attribution for A2. In the following training trials, two avatars appeared in the scene, A2 and A3, and the participants' correct responses, selecting which target was last seen from the designated avatar's perspective, were reinforced. The participants were only trained on the true belief attribution of A2 and A3, and the false belief attribution of A2. Then, in the final test phase, the false belief attribution of A3 was tested. This experiment is relevant to Spradlin and Brady's (2008) hypothesis that the outcomes of false-belief tasks may demonstrate discrimination between the stimuli currently available to the self (or a person, such as Figurine A2 in Guinther's (2018) study) and the stimuli available to another person (e.g., Figurine A3). Guinther's (2018) results supported this hypothesis.

Despite this initial evidence that the RT framework may be useful, some elements of the framework have not yet been tested. In both studies (Guinther, 2017, 2018), the interpersonal relation of coordination was deduced by the participants, and the stimulus functions (e.g., which Star Wars figurine the avatar "saw") during the test were the same as those directly trained. Thus, it was inconclusive as to whether the triangulated perspectives were influenced by the interpersonal alignment of "sameness," or if participants were simply repeating previously reinforced responses. As suggested by Guinther (2017), if non-equivalent interpersonal alignment were established, one could test for corresponding transformation of stimulus functions in the person-object sides of the triangle.

In the current study, we examined the derivation of Side 3 interpersonal alignment after Side 1 and 2 perspectives were established as either the same or opposite to each other. To accommodate the non-equivalence relations, baseline arbitrary relations among "person" stimuli were established with SAME and OPPOSITE relational frames. The participants were trained to respond as if some individuals (either avatars or arbitrary stimuli, depending on the group membership) were the same as or the opposite of each other, thus creating two “classes” of individuals. Participants were then taught to respond to arbitrary “target” stimuli in one way in the presence of ONE individual from one class, and the opposite way in the presence of ONE individual from the other class. Then, the transformation of the stimulus functions to the other members of the group was examined. In the final phase, responses to arbitrary “target” stimuli were trained in the presence of novel “person” stimuli; then interpersonal alignment (Side 3) was tested through a relational evaluation procedure (REP; Dymond et al., 2008; Stewart et al., 2004) to examine whether participants could derive the relationship between two individuals, being either same or opposite, based on the stimulus function of the target stimulus for the two observers (Side 1 and 2). With half of the participants, we conducted the experiment with arbitrary, non-social stimuli (e.g., geographical shapes) to evaluate the possibility that pre-established stimulus functions associated with social stimuli might influence the outcomes of the experiment.

Although Guinther (2017, 2018) employed a visuospatial task to validate the RT model, there is no requirement that the task must be visuospatial in nature. There are many examples of perspective taking that are not visuospatial in nature (e.g., predicting what gift another person will “like”). Therefore, we employed standard matching-to-sample (MTS) and relational evaluation procedures (REP) without any explicit visuospatial component (other than the positioning of the sample and comparison stimuli on the screen).

Method

Experiment 1

Participants

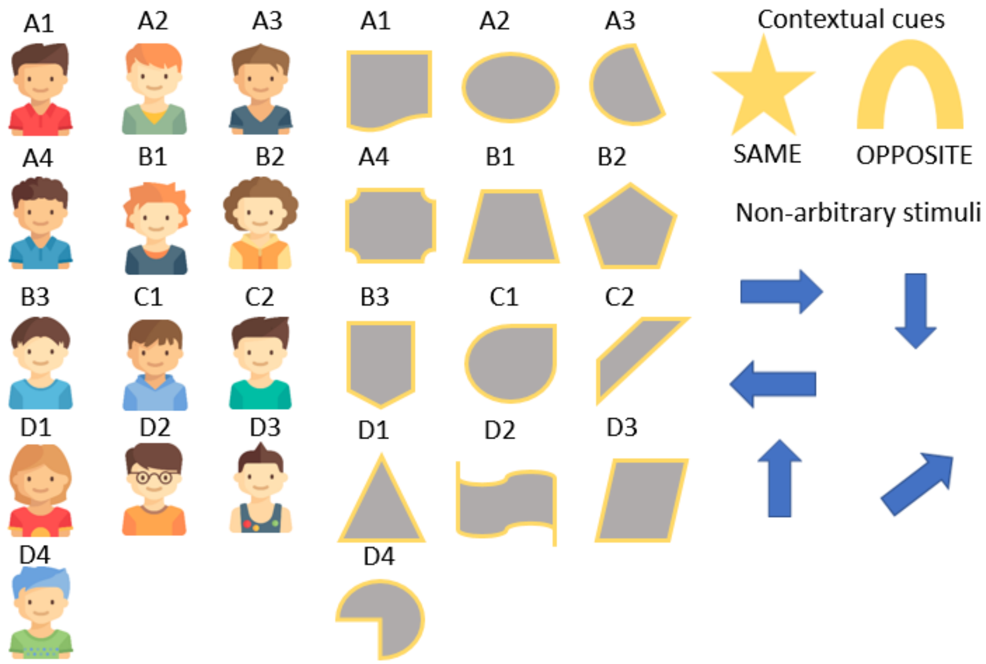
Twenty participants were recruited through flyers and online advertisements (through the School of Psychology). They were university students who were given the choice either to receive course credits (1% per hour of participation) or to enter a draw to win a $20 shopping voucher. The experiment was approved by the Division of Arts, Law, Psychology & Social Sciences Human Research Ethics Committee of the University of Waikato (FS2019-30).

Setting, Apparatus, and Materials

The experiment was conducted in a quiet room at the university, with an experimenter present. All experimental procedures were completed using a desktop computer and a monitor (Dell P2217 22-inch Led LCD monitor) located in the experiment room. Visual Studio 2017 (https://visualstudio.microsoft.com) and Three.js library (https://threejs.org) were used to present the experimental stimuli and the Google Drive API to record data. The statistical software SPSS (https://www.ibm.com/analytics/spss-statistics-software) was used for all analysis discussed in this paper. All participants were randomly assigned to one of two groups, a Social Group, which was exposed to facial stimuli in the experiment, and an Arbitrary Group, which was exposed to arbitrary shapes instead (Figure 2). The experimental stimuli were presented from left to right in a “sentence” format. For example, Stimulus A1 appeared at the left side of the screen, followed by a contextual cue (i.e., the stimulus for SAME or OPPOSITE), followed by a blank white square on the right side of the screen. Three to five comparison stimuli then appeared below the “sentence” stimuli; participants selected one comparison stimulus with the mouse (using the left click) and dragged it onto the white square above, releasing the left mouse button to “drop” the selected stimulus onto the white square. The sentence-like configuration is similar to the Relational Completion Procedure (RCP) used by Dymond et al. (2007; 2008; 2010), but we did not use selection-confirmation procedures to allow the participant to clear the selected comparison and to resume the trial, and we required no additional responses to proceed to the next trial.

Figure 2

Arbitrary stimuli (Face and Shape) and Non-arbitrary stimuli



Note. All stimuli were 4.5 cm wide and 5 cm high.

General procedure

The participants were provided with the following instructions printed on a piece of paper:

> You are going to do a series of computer tasks. What you need to do is to follow instructions and to respond using a mouse or pressing keys on a keyboard. The computer programme will inform you whether you are correct or not. Try your best to respond correctly each time. Some blocks of trials provide you with no feedback and, while you may feel like you are doing repetitive tasks, this is expected. You just need to focus on answering correctly in each trial. If you have any questions, please ask your experimenter. Once the experiment begins, she will not be able to answer questions about the programme. If you are ready, please press a spacebar to start.

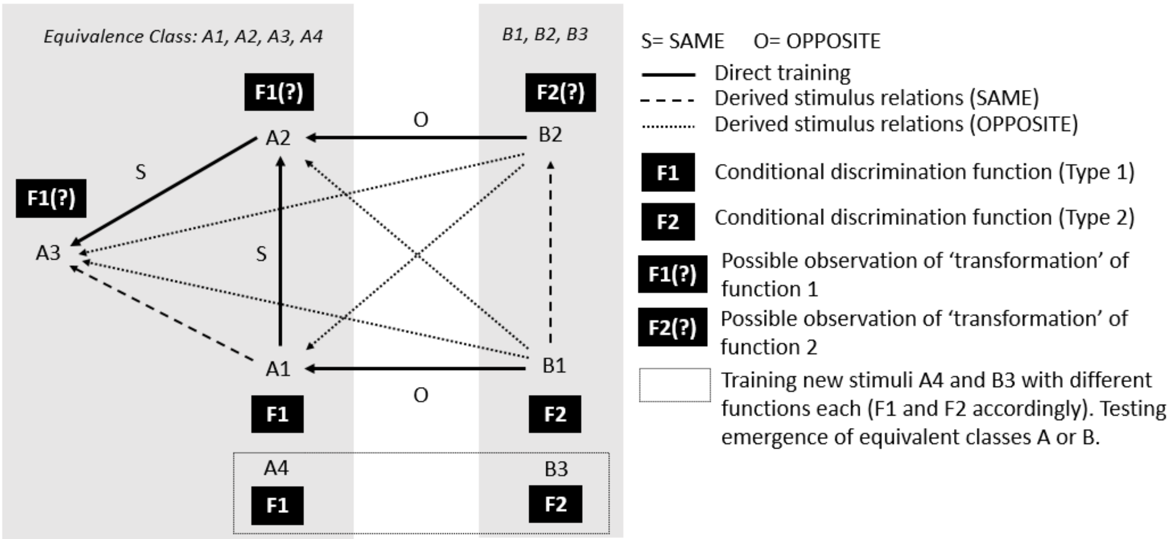
Phase 1: Non-arbitrary relational training. In Phase 1, participants learned to select physically identical stimuli in the presence of SAME (a star) and opposite stimulus features in the presence of OPPOSITE (an arch) through conditional-discrimination procedures. All the samples and comparisons were arrow stimuli pointing in five different directions (up, down, left, right, and diagonally upper right). Selection of an identical stimulus to the sample stimulus was followed by positive feedback (“Correct”) in the presence of the SAME stimulus, and by negative feedback (“Wrong”) in the presence of the OPPOSITE stimulus. Selection of the physically opposite stimulus (e.g., an arrow pointing in the opposite direction from the sample) was followed by positive feedback in the presence of the OPPOSITE stimulus, and by negative feedback in the presence of the SAME stimulus. For example, when a sample was an upwards arrow, selecting a downwards arrow was correct with the presence of OPPOSITE, but selection of any other stimulus (e.g., a left arrow) was incorrect. The experiment started with training trials for the SAME relations, then proceeded to the OPPOSITE relations. A training block had 10 trials per condition. Participants emitted 10 consecutive correct responses to progress to the next trial block.

Phase 2: Non-arbitrary relational testing. This phase followed the same trial arrangement as Phase 1, but with two exceptions. Firstly, no feedback was provided during the probe trials. Secondly, the two contextual cues (SAME and OPPOSITE) were combined in one test block with 12 trials (i.e., six trials for each of the two relations). Once the participants responded correctly to all trials in the test block, they were able to proceed to the next phase. If they failed, they repeated the whole trial (Phase 1 and Phase 2) until they achieved the mastery criteria in Phase2.

Phase 3: Arbitrary relational training. In Phase 3, a series of conditional-discrimination trials were provided to establish baseline relations among arbitrary stimuli A1, A2, A3, B1 and B2 as depicted in Figure 3. Arbitrary stimuli were used for all samples and comparisons (Figure 2). Following the naming convention used by Dymond et al. (2008), baseline training relations are expressed using the format: CONTEXTUAL CUE/sample stimulus followed by the comparisons in brackets, with the correct answer italicised (e.g., SAME/A1 [*A2*, B1, D1], where selecting A2 is reinforced and selecting B1 or D1 is not). All participants were trained with the following four baseline trainings: SAME/A1 [*A2*, B1, D1], SAME/A2 [*A3*, B2, D2], OPPOSITE/B1 [*A1*, B2, D1], and OPPOSITE/B2 [*A2*, B1, D2]. Training occurred with a block of six trials for each baseline relation. For example, participants were trained with the SAME/A1 [*A2*, B1, D1] first, followed by the SAME/A2 [*A3*, B2, D2] relation in two separate blocks of six trials each. After successful completion of these blocks, another block of a mix of the 12 trials containing the previous two baseline relations was provided, with participants required to respond correctly to all trials to pass the mixed training block. Feedback was provided for each response. Participants needed to answer all trials correctly to proceed to the next training block. Unsuccessful participants repeated the mixed training blocks until they met criterion. The remaining training blocks for the two OPPOSITE baseline relations were provided in the same manner as the aforementioned SAME baseline relations (i.e., one training block for each baseline relation, followed by a block containing a mix of both relations).

Figure 3

Schematic Representation of Experiment 1



Note. This figure indicates all of the training and testing trials examined in Phases 3 to 8. Emergence of the two equivalence classes, (A1, A2, A3, A4) and (B1, B2, B3) was tested in Phase 8 (the final phase). A1, A2, A3, A4, B1, B2 and B3 represent arbitrary stimuli. Arrows point from a sample to a designated comparison stimulus.

Phase 4: Arbitrary relational testing. In this phase, emergence of the untrained (derived) relations indicated in Figure 3 was examined using test trials without feedback. The following test trials were presented in random order: SAME/A1 [*A3*, B1, D2], SAME/B1 [*B2*, A3, D1], OPPOSITE/B1 [*A2*, B2, D3], OPPOSITE/B2 [*A1*, B1, D4], OPPOSITE/B2 [*A3*, B1, D3], and OPPOSITE/B1 [*A3*, B2, D4]. Each relation was probed six times, for a total of 36 probes in the test block. To pass the test block, participants needed to provide five correct responses (83% mastery criteria) for each relation. Those who did not pass the criteria were re-exposed to the two mixed training blocks for the SAME and OPPOSITE relations from the previous phase until they achieved mastery criteria again for each. After this re-training, they took the same test block again. Participants were allowed a maximum of four repeats of the cycle of mixed training blocks and the test block. Anyone who did not meet the testing criteria after the four repetitions was allowed to proceed to the next phase, because improved performance during testing is often observed after initial failures on equivalence tests (Holth & Arntzen, 1998; Sidman, 1994).

Phase 5: Establishing conditional discrimination functions. The main purpose of Phase 5 was to establish two different conditional discrimination stimulus functions, F1 and F2, for two stimuli, A1 and B1, respectively (see Figure 3). To train F1, when A1 appeared at the top of the screen and, after 1 second passed, another stimulus, S1 (a pink diamond), appeared, then pressing the spacebar (at least once within a 5-second interval) was reinforced. However, in the presence of A1, when S2 (a blue diamond) appeared, the inhibition of pressing the spacebar for 5 seconds was reinforced. To train F2, the opposite conditional discrimination was trained. When Sample B1 appeared and was followed by Stimulus S1, an inhibition of pressing the spacebar was reinforced. However, when Stimulus S2 appeared, pressing the spacebar was reinforced (see Table 1).

Table 1

Details of the Training and Test Trials from Phases 5 to 8

Phase 5: Trial details for each F1 and F2 functions	
F1	*F2*
A1 -> S1 [Pink Diamond] -> R1 [Pressing spacebar] -> "Correct"	B1 -> S1 [Pink Diamond] -> R2 [No Pressing] -> "Correct"
A1 -> S1 [Pink Diamond] -> R2 [No pressing] -> "Incorrect"	B1 -> S1 [Pink Diamond] -> R1 [Pressing spacebar] -> "Incorrect"
A1 -> S2 [Blue Diamond] -> R2 [No pressing] -> "Correct"	B1 -> S2 [Blue Diamond] -> R1 [Pressing spacebar] -> "Correct"
A1 -> S2 [Blue Diamond] -> R1 [Pressing spacebar] -> "Incorrect"	B1 -> S2 [Blue Diamond] -> R2 [No Pressing] -> "Incorrect"
Phase 6: Transfer of conditional discrimination function test	
F1	*F2*
A2 -> S2 [Pink Diamond] -> R2 [No pressing] -> Correct*	B2 -> S2 [Blue Diamond] -> R1 [Pressing spacebar] -> Correct*
A2 -> S2 [Pink Diamond] -> R1 [Pressing spacebar] -> Incorrect*	B2 -> S2 [Blue Diamond] -> R2 [No pressing] -> Incorrect*
A3 -> S2 [Pink Diamond] -> R2 [No pressing] -> Correct*	
A3 -> S2 [Pink Diamond] -> R1 [Pressing spacebar] -> Incorrect*	
Phase 7: Training details for each F1 and F2 functions	
F1	*F2*
A4 -> S1 [Pink Diamond] -> R1 [Pressing spacebar] -> "Correct"	B3 -> S1 [Pink Diamond] -> R2 [No Pressing] -> "Correct"
A4 -> S1 [Pink Diamond] -> R2 [No pressing] -> "Incorrect"	B3 -> S1 [Pink Diamond] -> R1 [Pressing spacebar] -> "Incorrect"
A4 -> S2 [Blue Diamond] -> R2 [No pressing] -> "Correct"	B3 -> S2 [Blue Diamond] -> R1 [Pressing spacebar] -> "Correct"
A4 -> S2 [Blue Diamond] -> R1 [Pressing spacebar] -> "Incorrect"	B3 -> S2 [Blue Diamond] -> R2 [No Pressing] -> "Incorrect"
Phase 8: A list of 18 pairs of stimuli to test an emergence of the two equivalence classes	
SAME	*OPPOSITE*
A4-A1; A1-A4; A4-A2; A2-A4; A4-A3; A3-A4 B3-B1; B1-B3; B3-B2; B2-B3	B3-A1; A1-B3; B3-A2; A2-B3; B3-A3; A3-B3; B3-A4, A4-B3

*No feedback presented during the test.

Before the start of the training trials, participants read the following instruction presented on the screen: "*After seeing two stimuli presented, you must either keep pressing the spacebar or not press at all. After each task, the computer will tell you whether you were right or not.*" Then, participants completed two separate training blocks for F1 and F2, each containing 12 training trials (Table 1). To pass each trial block, participants had to produce correct responses in every trial. Participants who met the training criteria proceeded to a block of 12 probe trials (a mix of F1 and F2 training trials) to assess their performance on discrimination of F1 or F2 functions for A1 and B1, respectively. They had to respond correctly to all probe trials to proceed to the next phase. If they failed, they returned to the beginning of Phase 5.

Phase 6: Test for transformation of the stimulus function. In this phase, we assessed the transformation of the stimulus functions (i.e., F1 or F2 conditional discrimination functions associated with A1 and B1) to the other members in the stimulus classes established in the previous phases (i.e., two classes A1, A2, A3 and B1, B2; see Figure 3). The format of the test trials was the same as in the Phase 5 training trials, except that no feedback was provided for responses in this test. We examined whether participants pressed the spacebar in the presence of A2, A3 and B2 stimuli in accordance with either the F1 or F2 function associated with A1 and B1 in the previous phase (see Figure 3). To ensure the retention of the established two classes acquired in Phase 3, participants were first exposed to two separate training blocks, one dedicated to each of the SAME and OPPOSITE baseline relations. These trials were identical to the training trials in Phase 3. The participants repeated this training block until passing it. This was followed by the test block for assessing the transformation of the stimulus functions F1 or F2 (see Table 1). The test block contained a total of 18 trials (six probes for each of the A2, A3, and B2 stimuli) and was presented only once. All participants proceeded to the next phase regardless of their performance.

Phase 7: Establishing F1 and F2 functions for novel stimuli (A4 and B3). Two novel stimuli, A4 and B3, were introduced, and F1 and F2 stimulus functions (i.e., spacebar pressing or no pressing) were established in the presence of each stimulus and the relevant conditional stimulus (S1 and S2), respectively (see Table 1). Separate training blocks containing 12 trials for F1 and F2 conditional-discrimination functions were presented in the same format as in the Phase 5 training trials. All participants were required to respond correctly to all training trials to proceed to the test block. The test block was a mix of 12 trials from the training blocks. No feedback was provided for responses in the test trials. The participants were required to answer correctly in all trials to proceed to the next phase. If they failed, then they returned to the beginning of Phase 7 and repeated the training and testing until they passed.

Phase 8: Derivation test of two functional equivalence classes. The purpose of this phase was to assess the emergence of the two functional equivalence classes after establishing function F1 and F2 for Stimuli A4 and B3, respectively, in the previous phase. Participants were tested to see whether they predicted an appropriate relation between the novel stimuli (A4 or B3) and members of the already established classes, (A1, A2, A3) and (B1, B2), by selecting the correct contextual cue (i.e., either SAME or OPPOSITE). This transfer of stimulus control represents the derivation of a relation based on the function of a stimulus (an Observer A) with respect to another observer (B), represented as Side 3 or interpersonal alignment, in the triangulation model (Figure 1). Participants were exposed to 18 untrained pairs of stimuli, for a total of 54 probe trials (i.e., three trials for each pair of stimuli) (see Phase 8 in Table 1). Before proceeding to this test block, participants read the following instruction presented on the monitor:

> After seeing two stimuli presented, you will make a response by dragging one of the stimuli to the blank square on the monitor. This time there will be no feedback for your response.

The test trial was presented in a slightly different format from the previous sessions. A correct response was the selection of the arbitrary contextual cue corresponding with either SAME or OPPOSITE (i.e., the star or the arch) when presented with a pair of stimuli. A sample (e.g., A1) appeared on the left, then a blank square space appeared in the middle where a contextual cue of either X1 (SAME) or X2 (OPPOSITE) had been located in the previous series of training and test trials. One second later, another sample stimulus (e.g., B4) appeared to the right side of the white blank square in the middle. Subsequently, the two contextual cues X1 and X2, whose positions were randomly altered, appeared at the bottom area of the screen as comparisons. The participant selected one of them and dragged and dropped it into the blank square located in the middle area of the top panel. Once the participants finished the 54 test trials, the screen showed a message telling them they had reached the end of the experiment and instructed them to notify the researcher.

Experiment 2

Twelve of the 20 participants in Experiment 1 failed to achieve the mastery criteria (two out of three correct trials for each of the 18 different probes) in the Phase 8 test trials. Approximately half of the participants also failed to meet the criteria in a pilot study, which was conducted prior to Experiment 1; in this study, seven out of 15 participants did not meet the criteria to pass the test. In both cases, the participants who did poorly in Phase 8 also tended to perform poorly in the Phase 4 probes for derivation of the untrained arbitrary stimulus relations, especially on the trials testing for equivalence (i.e. SAME/B1 [*B2*, A3, D1] see Figure 3) that was supposed to be derived from two explicitly trained *OPPOSITE* relations (i.e., OPPOSITE/B1 [*A1*, B2, D1] and OPPOSITE/B2 [*A2*, B1, D2]). On the other hand, participants performed well when deriving the equivalence class (A1, A2, A3) from the explicit training with trials using SAME/A1 [*A2*, B1, D1], SAME/A2 [*A3*, B2, D2]). This led us to believe that the failure to derive untrained stimulus relations based on SAME and OPPOSITE relational framing may be the underlying problem leading to failure in Phase 8. Rather than relying on the participants' pre-experimental history of responding in accordance with *same* and *opposite* relations with arbitrary stimuli, in Experiment 2, we aimed to provide the relevant history of reinforcement. This was done by providing feedback during the initial test phase instead of immediately moving onto the testing phase under extinction conditions. This strategy of giving some feedback during the test phase is often practiced in equivalence studies involving animals to avoid establishing experimentally unintended stimulus relations. This is because the subjects may perceive the absence of reinforcement as a consequence of their error responses (McIlvane, 2013; McIlvane & Dube, 1996; Schusterman & Kastak, 1993; Sidman, 2008). We hypothesised that this modification to the procedure would facilitate performance when deriving SAME and OPPOSITE relations with novel stimuli.

Therefore, in Experiment 2, we modified the training and testing conditions in Phases 3 and 4 as follows. In Phase 3, in which baseline relations among A1, A2, A3, B1 and B2 were established, we provided an additional block of trials with feedback given to the series of stimulus pairs with relations that could, in principle, be derived from the baseline relation training. The feedback was provided to increase the accuracy of SAME and OPPOSITE relational responding, with the intention that this additional block of trials would establish the relational responding used in the "real" test trials in Phase 4, by providing direct training with high accuracy criterion. Participants were not allowed to proceed to the next phase until they met all the criteria. They then proceeded to a set of probe trials that contained the same stimulus pairs provided in the previous phase, except that two novel stimuli were introduced in Phase 4. Participants were examined for relational responding based on the SAME and OPPOSITE framing as a generalised operant. The block of probe trials was provided under extinction conditions, in the absence of feedback. In addition, at the end of the experiment, we added two post-experimental questions asking participants to describe the meaning of the SAME and OPPOSITE contextual cues. The rest of the procedures in Experiment 2 remained the same as in Experiment 1.

Participants

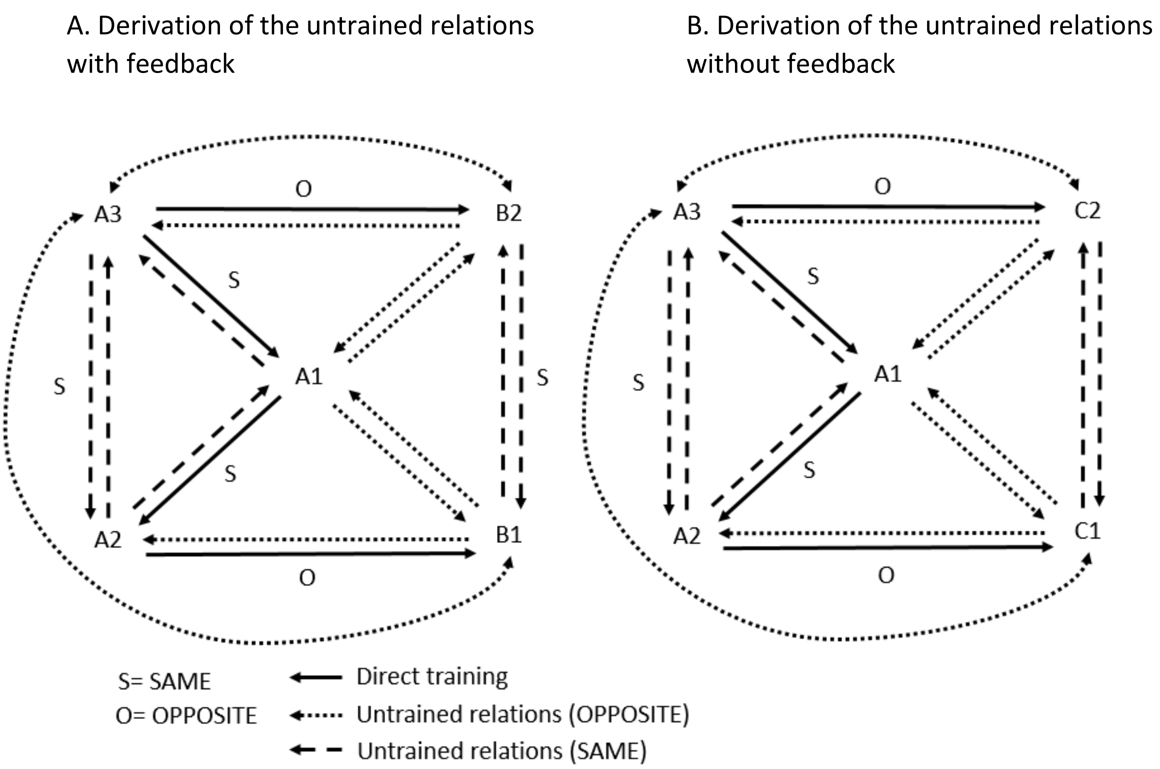
We recruited 16 new participants following the same procedure as in Experiment 1. They were randomly assigned to either the social or the arbitrary stimuli groups.

Procedure

Phase 3: Arbitrary relational training and testing. In this phase, a series of conditional discrimination trials were provided to establish baseline relations among arbitrary stimuli A1, A2, A3, B1 and B2 to ensure that participants had a history of reinforcement for deriving SAME and OPPOSITE relations with arbitrary stimuli. All participants were trained with the following four baseline relations, which were presented in a slightly different configuration compared to the Phase 3 trials in the Experiment 1. In Experiment 2, A stimuli were presented as sample stimuli and B stimuli as comparison stimuli (this was the opposite arrangement from Experiment 1): SAME/A1 [*A2*, B1, D1], SAME/A3 [*A1*, B2, D2], OPPOSITE/A2 [*B1*, A1, D1] and OPPOSITE/A3 [*B2*, A2, D2] (Figure 4-A).

Figure 4

Schematic Representation of the Experiment 2



Note. The diagram shows the training trial context presented during Phase 3 (Figure A on the left) and the test trial context in Phase 4 (Figure B on the right). Feedback was provided for responses in the tests for derived (untrained) relations indicated as dotted lines in Phase 3. In Phase 4, however, no feedback was provided to see if participants would produce generalised transitivity and equivalence with the novel stimuli, C1 and C2, based on the B1-B2 equivalence relation that was established with direct feedback in Phase 3.

Training occurred with a block of six trials featuring a single baseline relation provided in the same trial format as in Experiment 1. However, unlike Experiment 1, two additional test blocks (12 trials each) were provided to examine symmetry for each of the four baseline relations; the symmetry tests for the SAME/A2 [*A1*, B1, D1] and SAME/A1 [*A3*, B2, D2] relations were provided in the first block, followed with the second block for testing the OPPOSITE/B1 [*A2*, B2, D1] and OPPOSITE/B2 [*A3*, B1, D2] relations. Those symmetry test blocks were provided immediately after the relevant baseline training blocks. No feedback was provided during the symmetry test. To proceed to the next step, participants produced 10 consecutive correct responses for each symmetry test block. Making more than two errors during the test block resulted in participants receiving retraining on the relevant relations until they met the criteria to pass. Following this, we provided a block of reinforced probe trials to assist the derivation of the relational responding used in the Phase 4 test trials. The aim of the reinforced probe trials was to establish a history of reinforcement for relational responding associated with same and opposite relations that correspond with baseline relations (see the left column in the Table 2).

Table 2

Stimulus Arrangement for Test Trials in Phase 3 and 4

Phase 3: Test trial details	Phase 4: Test trial details
SAME/A2 [A3, B1, D2]	SAME/A2 [A3, C1, D2]
SAME/A3 [A2, B2, D1]	SAME/A3 [A2, C2, D1]
SAME/B1 [B2, A3, D2]	SAME/C1 [C2, A3, D2]
SAME/B2 [B1, A2, D1]	SAME/C2 [C1, A2, D1]
OPPOSITE/B1 [A1, B2, D2]	OPPOSITE/C1 [A1, C2, D4]
OPPOSITE/A1 [B1, A2, D1]	OPPOSITE/A1 [C1, A2, D3]
OPPOSITE/B2 [A1, B1, D2]	OPPOSITE/C2 [A1, C1, D4]
OPPOSITE/A1 [B2, A2, D1]	OPPOSITE/A1 [C2, A2, D3]
OPPOSITE/B2 [A3, B1, D2]	OPPOSITE/C2 [A3, C1, D4]
OPPOSITE/A3 [B2, A2, D1]	OPPOSITE/A3 [C2, A2, D3]
OPPOSITE/B1 [A3, B2, D2]	OPPOSITE/C1 [A3, C2, D4]
OPPOSITE/A3 [B1, A2, D1]	OPPOSITE/A3 [C1, A2, D3]

The test block including feedback contained a total of 36 trials (i.e., three trials for each relation), randomly presented during the test block. Participants were required to provide correct responses for at least two trials for each untrained relation. They were not allowed to proceed to the next phase until they met these criteria.

Phase 4: arbitrary relational training and testing with novel stimuli. In this phase, two sets of novel stimuli, C1 and C2 (Figure 2 & 4), were introduced, replacing the B1 and B2 stimuli used in the previous phase. This was to see if participants would respond with higher accuracy in deriving a series of untrained arbitrary relations compared to the participants in Experiment 1 (see the right column in Table 2). In addition, this procedure was designed to test whether the participants would increase accuracy on SAME/C1 [*C2*, A3, D2] and SAME/C2 [*C1*, A2, D1] probes after being directly trained that two OPPOSITE stimuli are the same, SAME/B1 [*B2*, A3, D2] and SAME/B2 [*B1*, A2, D1]. Every other stimulus used remained unchanged from the previous phase. The baseline training and symmetry tests were in the same format as in the previous phase, but with a few exceptions. First, the baseline training and symmetry for the SAME relations (i.e., explicitly training A3=A1, A1=A2 relations and derived symmetry of A1=A3 and A2=A1) were removed from Phase 4 because the participants already achieved successful performance in these in the previous phase. Thus, the participants were only trained on the two OPPOSITE baseline relations with the new stimuli (i.e., OPPOSITE/A2 [*C1*, A1, D3] & OPPOSITE/A3 [*C2*, A2, D4]), and we tested symmetry for each relation (i.e., OPPOSITE-C1 [*A2*, A1, D3] OPPOSITE-C2 [*A3*, A2, D4]). Secondly, in the final test block assessing derivation of the 12 relations, no feedback was given this time, and there were no repetition criteria arranged for the test block (right column on the Table 2).

After completing Phase 8. After participants completed the Phase 8 test block in Experiment 2, two questions appeared sequentially on the monitor, and the participants were instructed to fill in the blank space below each question. The first question was "What do you think [the picture of the "star" stimulus] means in this experiment?" and the second was "What do you think [the picture of the "arch" stimulus] means in this experiment?"

Results

Phase 4: Result of the derivation on untrained stimulus relations

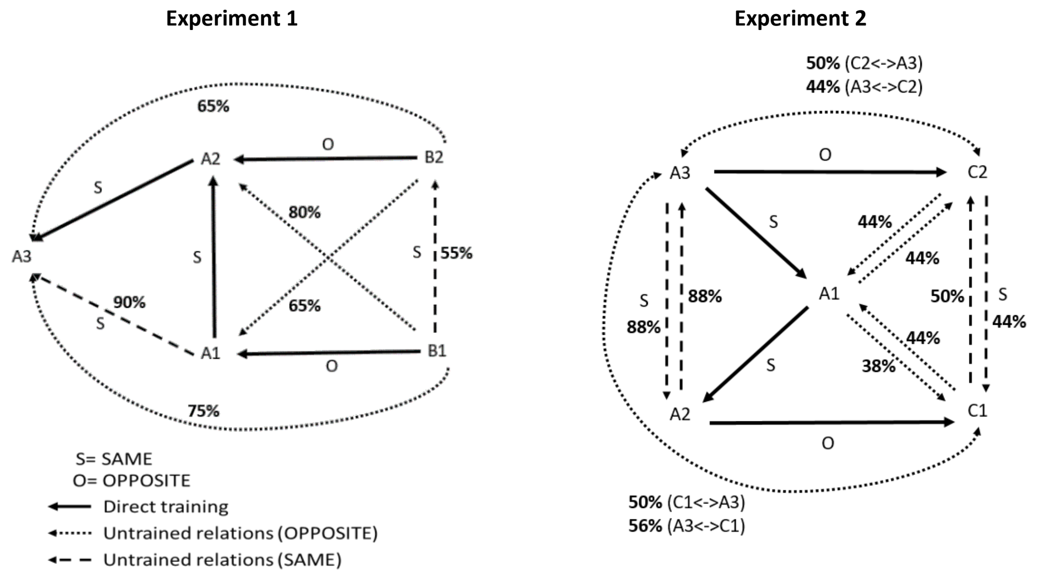
In Phase 4, the derivation of six different untrained stimulus relations in the same/opposite framework was examined. The mastery criterion was set as 83% (i.e., one error was allowed in a total of six trials per each relation). The participants were allowed to repeat the block of test trials up to four times before moving on to the next phase regardless of their performance. Across both Experiment 1 and 2, only 8.3% of participants (two out of 20 in Experiment 1, and one out of 16 in Experiment 2) met the criterion to pass Phase 4.

Even though our results show a small percentage of participants were able to master the criteria for this phase, the average rate of correct responses emitted for *each* derived stimulus relation gives a different view of the performance results (see Appendix A, which provides a detailed overview of the average number of correct responses across participants in each trial type). Of particular note is the participants' difficulty in forming the equivalence class based on the explicitly trained stimulus relations involving multiple OPPOSITE contextual stimuli (e.g., if A1 is opposite to B1 and A2 is opposite to B2, then B1 is same as B2). In Experiment 1, incremental increases in correct responses were observed across repeated test sessions (i.e., Sessions 1–4 in the Appendix A) for all the other derived relations, except the equivalence relation that was supposed to be derived from the double OPPOSITE relations. All participants repeated the test sessions four times. High percentages of correct responses were emitted for the derivation of equivalence relations (87% for SAME/A1 [*A3*, B1, D2] in Experiment 1 and 80% for SAME/A2 [*A3*, C1, D2]; 84% for SAME/A3 [*A2*, C2, D1] in Experiment 2). However, the participants performed poorly (with less than 60% accuracy) in deriving the double-OPPOSITE relations (44% for SAME/B1 [*B2*, A3, D1] in Experiment 1 and 51% for SAME/C1 [*C2*, A3, D2]; 44% for SAME/C2 [*C1*, A2, D1] in Experiment 2).

Figure 5 displays the percentage of participants who met the mastery criteria for deriving the experimentally expected relations across all the different derivation of the stimulus relations. The purpose of Figure 5 is to visualise the points described above by looking at the data using different criteria based on the pass rate, which also shows the same pattern of results. At least 88% of the participants passed the equivalence relation trials; however, they performed poorly (with less than 50% of the participants meeting the criteria) in deriving equivalence relations out of the two explicitly trained oppositional relations (see Appendix A).

Figure 5

Percentage of Participants Showing Successful Derivation



Phase 6: Result of the transformation of the stimulus functions, F1 and F2

In Phase 6, the participants were tested for their derivation of the transformation of the stimulus functions (i.e., F1 or F2 conditional discrimination functions associated with A1 and B1 stimuli) to other members in the equivalence classes, A2, A3 and B2. Across both Experiment 1 and 2, 36% (13 out of 36) of participants met the requirement of more than 83% correct responses. Specifically, 35% (seven out of 20) met the criteria in Experiment 1, and 37.5% (six out of 16) did in Experiment 2 (see Table 3).

Table 3

The Percentages of Experimentally Planned Derivation of the Transformation of Stimulus Function (F1 or F2) for each participant

Experiment 1

Participants	F1 response to A2 (%)	F1 response to A3 (%)	F2 response to B2 (%)	Mean % of the three derivations
1	33	50	50	*44*
2	100	0	100	*67*
3	50	83	33	*55*
4	83	100	33	*72*
5	100	100	100	*100*
6	0	67	17	*28*
7	100	100	100	*100*
8	0	0	0	*0*
9	100	100	100	*100*
10	67	50	50	*56*
11	100	83	100	*94*
12	100	83	100	*94*
13	100	83	100	*94*
14	50	0	17	*22*
15	100	100	100	*100*
16	0	17	100	*39*
17	67	83	67	*72*
18	83	50	50	*61*
19	50	67	67	*61*
20	0	83	50	*44*

Experiment 2

Participants	F1 response to A2 (%)	F1 response to A3 (%)	F2 response to B2 (%)	Mean % of the three derivations
1	100	83	100	*94*
2	100	100	67	*89*
3	0	0	33	*11*
4	100	100	100	*100*
5	100	100	83	*94*
6	17	17	17	*17*
7	50	0	0	*17*
8	50	100	67	*72*
9	100	100	100	*100*
10	67	100	83	*83*
11	50	50	0	*33*
12	0	50	0	*17*
13	100	50	83	*78*
14	83	0	83	*55*
15	30	30	50	*37*
16	67	50	17	*45*

Note. This table demonstrates the accuracy of derivation of each participant on the transformation of conditional discrimination function upon the presence of A2, A3 and B2 stimuli. The experimentally expected responses are labelled on the sub-headings. The “F1 response to A2” and “F1 response to A3” mean that upon the presence of the A2 or A3 stimulus, the participant was expected to emit the F1 conditional responses (i.e., tapping on the spacebar at least once within 5 seconds in the presence of a pink diamond-shape stimulus, and an absence of tapping in the presence of a blue diamond shape). In the presence of the B2 stimulus, the participant was expected to respond in accordance with the F2 function (i.e., tapping on the space bar when presented with a blue diamond shape, and the absence of tapping response when presented with a pink diamond).

Phase 8: Result of the derivation of the two equivalence classes and evaluation of the SAME or OPPOSITE stimulus relations

In Phase 8, the emergence of the two equivalence classes (A1, A2, A3, A4) and (B1, B2, B3) were examined through the participants’ prediction for the two relations of the presented pairs of untrained stimuli by selecting either SAME or OPPOSITE contextual cues (see Table 1). Across the two experiments, 47.2% of participants (17 of 36) reached the criteria, which was set for emitting two correct responses of the three test trials per each untrained pair of stimuli, and in total, there were 54 test trials, using 18 different stimuli pairs (see Table 1). In Experiment 1, 40% of the participants (eight out of 20) and in Experiment 2, 56% of the participants (nine out of 16) demonstrated evidence of establishing the 4- and 3-member functional equivalence classes (A1, A2, A3, A4) and (B1, B2, B3). Through appropriately evaluating the relations between the two classes by selecting either the

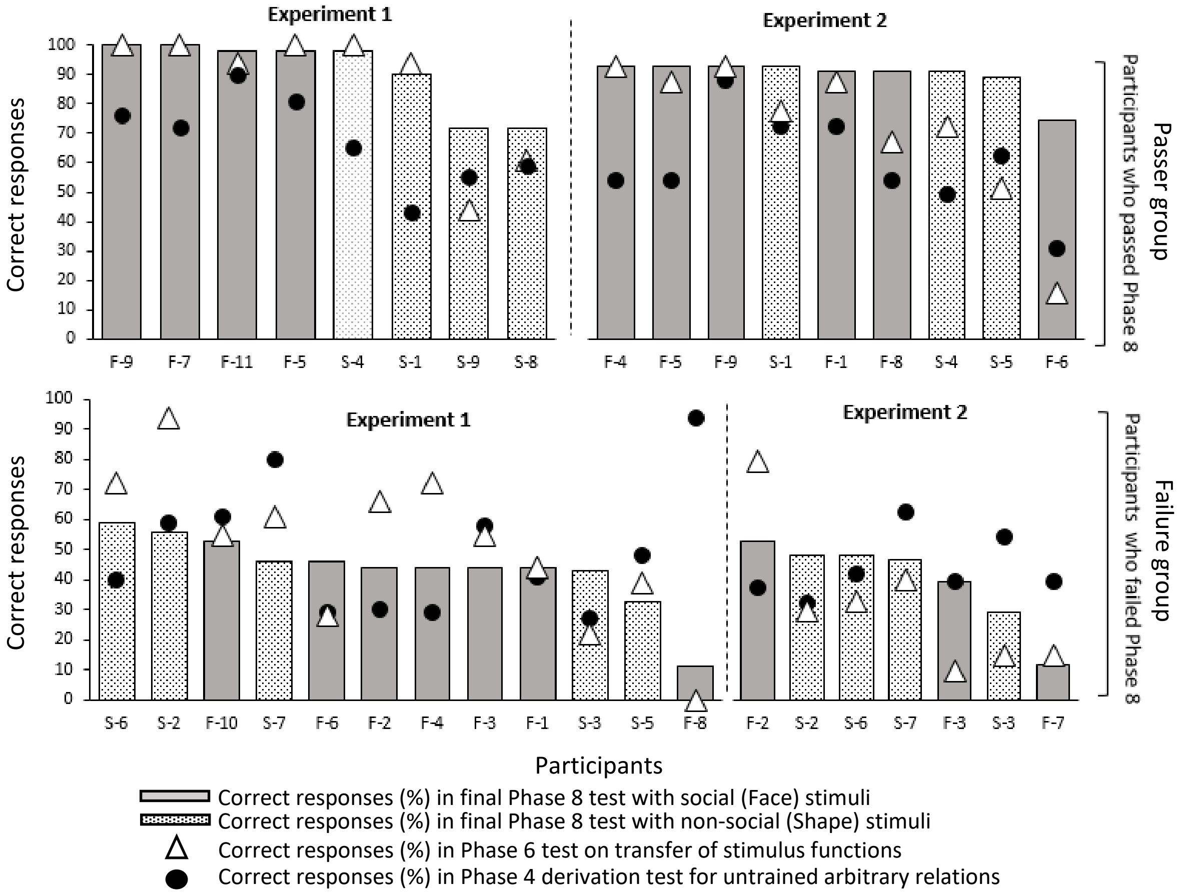
SAME or OPPOSITE contextual cue, the participants predicted which classes (i.e., the class of A stimuli or the class of B stimuli) either one of the novel stimuli (A4 and B4) belonged to. The participants' derivation of the appropriate stimulus relations of the two novel stimuli with the already established equivalence classes demonstrated the prediction (or inference) of the perspectives (whether it was the SAME or OPPOSITE relations) between an individual A and another individual B based on the discrimination of the history of reinforcement (i.e., F1 or F2 conditional discrimination history) associated with each individual (Figure 1).

Overall analysis of Phases 4, 6, and 8

Figure 6 shows the results from Phases 4 and 6 together, by assigning the participants to one of two separated groups based on those who met the criteria to pass the Phase 8 test (see the top two graphs "passer group") and those who did not (the bottom two graphs, "failure group"). Compared to those who passed the Phase 8 test, about half of the participants (53%; 19 out of 36) did not meet the criteria to pass the evaluation test of SAME and OPPOSITE relations in Phase 8. The overall performance observed in both Phases 4 and 6, however, predicted the result in the Phase 8 outcome. A Pearson's correlation analysis indicated a moderate positive correlation between the test results of Phase 4 and Phase 8 [$r = .4$, $n = 36$, $p = .02$], Phase 4 and Phase 6 [$r = .38$, $n = 36$, $p = .02$], and a large positive correlation between the test results of Phase 6 and Phase 8 [$r = .8$, $n = 36$, $p < .001$]. The moderate correlation between the Phase 4 and Phase 8 results aligns with the better performance observed in the passer group. Participants in this group provided an average of 57% correct responses in the Phase 4 test in Experiment 1, and 64 % in Experiment 2, compared to the performance produced by those in the failure group who scored an average of 29 and 49%, respectively. The passer group also did well in Phases 6 and 8. Of 13 participants who met the criteria of passing the Phase 6 transformation of stimulus function test, 11 were also part of the passer group in the Phase 8 test.

Figure 6

Percentage of Correct Responses Emitted in Three Test Phases in Experiment 1 and 2



Note. The two figures at the top indicate the percentage of correct responses emitted in Phases 4, 6, and 8 by participants who met the accuracy criteria in the Phase 8 test (assessing derivation of two functional equivalence classes of A vs. B stimuli based on F1 and F2 functions respectively). The two figures at the bottom indicate the performance of those who failed the Phase 8 test. Participant numbers are indicated on the horizontal axis. Participant numbers starting with F indicate participants in the Face Stimulus (i.e., social stimuli) group, and S indicates participants in the Shape Stimulus (i.e., arbitrary stimuli) group.

Social and arbitrary stimuli groups

No significant difference was observed between the social and arbitrary stimuli groups among all of the Phase 4, 6 and 8 test performance results of the combined Experiment 1 and 2 data. A mixed ANOVA with repeated measures analysing the percentage of correct responses in the three phases concluded no significant difference was observed in the mean correct responses between the social and arbitrary groups, $F(1, 34) = .58$, $p = .45$, $\eta_p^2 = .02$. All the assumptions of the statistical tests were met. Box's test showed homogeneity of covariance matrices, $F(6,8074.4) = .69$, $p = .66$ and

Mauchly's sphericity test for the repeated measures showed the assumption of a repeated-measures ANOVA being met, W = .9, X^2 (2) = 3.34, p = .19. For Phase 8, the Chi-square test of independence was conducted separately. No effects were found in the number of participants meeting mastery criteria to pass the Phase 8 test between the two groups, $X^2(1) = .14$, $\varphi = -.06$, $p = .71$.

Post-experiment text

Table 4 and 5 summarise responses to the post-experiment questions provided at the end of Experiment 2, which asked participants what they thought the contextual SAME (star) and OPPOSITE (arch) stimuli meant in the experiment. Most of the participants who did well in the Phase 8 test identified the star contextual cue as meaning "same" or "similar" (as experimentally planned); however, descriptions for the arch contextual cue included mixed notions of both "different" and "opposite."

Table 4

Textual Responses Made by Participants Who Did Well on the Phase 8 Test to the Post-Experimental Text Questions about What a Star or an Arch Stimulus Meant at the End of Experiment 2

Participants	Star (SAME)	Arch (OPPOSITE)
F-4	The same as	Different than
F-5	Same or shares some similarity (such as gender)	Different in someway or opposite
F-9	Same or similar	Opposite or different
S-1	The same / equal	Opposite
F-1	in the same category as	in the opposite/adjacent category
F-8	The same	Different
S-4	The same	Opposite
S-5	most similar to	the most different to
F-6	Same	Different

The other half of the participants, who failed in the Phase 8 test, seemed not to have developed the experimentally defined functions, especially for the OPPOSITE contextual cues (Table 5).

Table 5

Textual Responses, made at the End of Experiment 2, by Participants Who Failed in the Phase 8 Test to the Post-Experimental Text Questions, about What a Star or an Arch Stimulus Meant.

Participants	Star (SAME)	Arch (OPPOSITE)
F-2	similar position or view	different position or view
S-2	Could not tell	Could not tell
S-6	that certain shapes are paired together	That the previous pairs from the star symbol should be swapped around
S-7	most similar to	the most different to
F-3	Similarities	Spontaneousness
S-3	Similar object shape	Different object shape
F-7	the same as	Not the same

Discussion

We evaluated the utility of Guinther's (2017, 2018) Relational Triangulation (RT) framework for understanding perspective taking involving interpersonal relationships of "same" and "opposite." In Guinther's original experiments, only interpersonal relations of equivalence were examined, and it was unclear whether the derived responses were the result of the contextual control exerted by the specific contextual stimulus of *same*, or whether the responses were influenced by other types of contextual stimuli available in the experimental context. Additionally, we evaluated the utility of the protocol in tasks without an explicit visuospatial element. In both Experiments 1 and 2, we observed that approximately half of the participants successfully demonstrated 4- and 3-member equivalence classes, (A1, A2, A3, A4) and (B1, B2, B3). These participants demonstrated functional equivalence by deriving the most appropriate relational stimulus (either *same* or *opposite)* associated with the interpersonal alignment between "person" stimuli, based on the two different stimulus functions of a target stimulus associated with each "person." This finding was also supported by the retrospective reports showing the participants' understanding of the two differential functions for each contextual cue (e.g., SAME as "similar to" and OPPOSITE as "opposite to"). The RT model accurately predicted the derivation of other perspectives when participants demonstrated adequate contextual control by stimuli associated with two given sides of the triangle.

As a part of our approach to understanding the structural aspect of the RT framework, the stimuli presented in the current study were all arbitrary stimuli, except for the arrow stimuli used in the pre-training phase to establish the two contextual stimuli (SAME and OPPOSITE) and the facial stimuli used in the non-arbitrary stimuli experimental group. The purpose of this stimulus selection was to determine if the RT framework works in the absence of stimuli that are likely to have pre-existing stimulus functions that are relevant to perspective-taking problems. We found no significant difference between the number of participants who met the criteria for trials in the face- or the shape-stimulus experimental groups. This finding suggests that the provenance of the stimulus function may not impact the utility of the RT model in terms of predicting the outcome of perspective-taking tasks that align with the model. However, further studies are required to confirm this result, possibly by applying other types of social stimuli or relevant stimuli functions.

Among the other half of the participants in the current experiments, those who did not demonstrate the establishment of the equivalence classes, performance on all three tests remained poor throughout. This includes performance on the Phase 4 test for deriving arbitrary relations, the Phase 6 test on transfer of stimulus functions, and the Phase 8 test for the emergence of the two functional equivalence classes. The accuracy in deriving untrained arbitrary stimulus relations remained below 50%, on average, in both Experiments 1 and 2. This apparent failure was perhaps caused by a lack of exemplars during the initial pre-training phase. We relied on a single type of non-arbitrary exemplar (a set of arrowhead stimuli), which may have been insufficient to establish stimulus control by SAME and OPPOSITE contextual stimuli. The verbal responses to the post experimental question in the current experiment indicated that those who did not pass the final Phase 8 test were confused about what the OPPOSITE stimulus function was, though they were able to correctly describe what the SAME stimulus referred to. Alternative or additional stimuli could include positions, temperatures (– and +), and contrasting colours (black and white) to strengthen the degree of stimulus control associated with the two contextual stimuli. Previous studies on SAME/OPPOSITE relations, adapted from the original work by Steel and Hayes (1991), typically offered five to six different physical dimensions of exemplars, such as lines, cubes, and dots. Almost all the participants[4] in the previous studies met the criteria to pass the arbitrary relational testing phase, which was similar to our Phase 4 derivation test. Their participants were required to provide a minimum of 90% correct responses to pass the test phase (i.e., allowing one or two errors per block of testing trials) and if the criteria were not reached, a maximum of three to four exposures of a training and testing sequence was allowed.

However, the insufficient numbers of exemplars during the pre-training phase may not be in itself a sufficient explanation for the finding that the majority of the participants did not pass the Phase 4 test for deriving untrained arbitrary relations (i.e., only three individuals met the criteria in both Experiment 1 and 2 combined). This is because those who passed the final Phase 8 test for deriving two functional equivalence classes, which could not have been achieved without being under the control of the contextual stimuli of SAME and OPPOSITE, also performed poorly in the Phase 4 derivation test. We observed that error responses were rarely made in trials that only involved equivalence relations, but were frequently made in trials that involved opposition relations. This was especially apparent when participants faced difficulty in deriving the combinatorial entailment that a relation of an opposite of an opposite is the same (e.g., if A1 is opposite to B1 and A2 is opposite to B2, then B1 is the same as B2; participants performed this derivation with less than 60% accuracy).

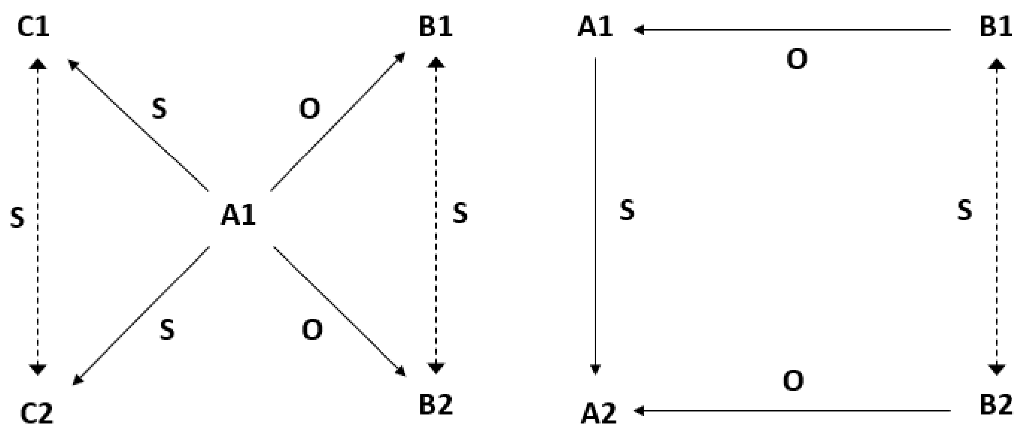
The poor testing performance observed in Phase 4 may have been affected by the difference in the stimulus configurations used in our experiment compared to the previous RFT studies on SAME and OPPOSITE relations (Bennett et al., 2015; Cassidy et al., 2011; Dymond et al., 2007, 2008, 2013; Dymond & Whelan, 2010; Roche & Barnes, 1997; Roche et al., 2000; Steele & Hayes, 1991; Stewart et al., 2015; Whelan & Barnes-Holmes, 2004). The previous studies involved only a single A1 sample stimulus in the training phase (i.e., many-to-one training), that was constantly

[4] The number of participants who failed to derive untrained arbitrary relations in previous studies was reported as usually just one or two individuals (i.e., under 15%; see Dymond et al., 2007, 2008). However, there were some exceptions in the previous studies in which researchers reported the number of participants who failed to pass the test as being closer to 50% (Dymond et al., 2013; Dymond & Whelan, 2010). The nature of this failure was not specifically discussed, as both studies reported a higher rate of passing in the derivation test using an alternative training procedure (as opposed to the conventional matching-to-sample procedure), the Relational Completion Procedure (RCP).

presented with the contextual cues (SAME and OPPOSITE) being the only thing changing (other than the comparison stimuli). Stimulus classes may be more readily formed in such cases (Figure 7, left). For instance, when relations such as SAME-A1-C1 and SAME-A1-C2 are trained first, it is possible to derive a stimulus class containing C1 and C2. Likewise, learning OPPOSITE-A1-B1 and OPPOSITE-A1-B2 may lead to the formation of a class of B1 and B2. In this case, the different functions of contextual stimuli acquired during the pre-training would not necessarily play a part in the formation of the two classes. However, the current experiment included two anchor stimuli (A1 and A2) to establish the OPPOSITE relations with the other corresponding stimuli (B1 and B2) during training (Figure 7, right), which may have made derivation of the B1 and B2 class more difficult because derivation of this class relied upon combinatorial entailment to the effect that "the opposite of the opposite is the same."

Figure 7

Diagram of Trained and Tested Stimulus Relations



Note. Alphanumeric combination represents arbitrary stimuli used in training and testing. The letters S and O indicate "Same" and "Opposite," respectively. Solid lines represent directly trained relations; dashed lines represent derived relations. Both diagrams partially depict the stimulus configuration employed during an experiment. These figures outline the difference in the stimulus arrangement that features the combinatorial entailment in a relation of an *opposite* of an *opposite* being the *same* between the current study and the previous studies.

According to RFT, derived responding of the equivalence relation between B1 and B2 would not be possible without the contextual control of the OPPOSITE relational framing (Steele & Hayes, 1991). However, the well-organised stimulus arrangement employed in the previous RFT studies (i.e., A1 stimulus remained as a sample and was not used as a comparison) may facilitate establishment of the equivalence class. This is only speculation, but it is related to the findings from some studies that have provided an alternative explanation to the existing SAME and OPPOSITE relational framing paradigm and have demonstrated an emergence of relational responding through binary responding of equivalence or non-equivalence; the researchers achieved this without providing the pre-training, involving non-arbitrary stimuli, to establish the contextual control of SAME and OPPOSITE relations (Alonso-Álvarez, 2019; Alonso-Álvarez & Pérez-González, 2017, 2018, 2021; Alonso-Álvarez & Wu, 2022 and Stewart et al., 2019 as a response to Alonso- Álvarez et al. 2017, 2018). A replication study on SAME and OPPOSITE relational framing, based on a different stimulus configuration (e.g., the right side of Figure 7), may be required to clarify the functional relations between multiple contextual stimuli, including those associated with the stimulus configuration during training, and derived responding.

One limitation of the current study is that negative comparisons (i.e., D stimuli) were not arranged to appear equally across the arbitrary relations training and test trials in Phases 3 and 4 of Experiments 1 and 2. Novel distractor stimuli (D3 and D4) were arranged during a block of test trials to avoid unexpected influence over participants' test performance as a result of having D1 and D2 stimuli presented in the training phase. However, the distracter stimuli, D3 and D4, only appeared in the test trials for OPPOSITE relations, not during the test trials for SAME relations. This was a mistake, though fortunately the rate of selecting the distractors remained low throughout (less than 10%). We cannot neglect the possibility, however, that this may have contributed to the poor performance in deriving OPPOSITE relations during the Phase 4 test, especially during Experiment 2 in which the selection rate of the distractor stimulus exceeded 20% in some of the tasks (see Appendix A). Future studies should build on the work of Fields et al. (2010), Fucini (1982), and Johnson and Sidman (1993) to further address the influence of negative stimuli. The consistency in appearance of the negative comparison stimuli may be an important source of control in stimulus equivalence.

Conclusion

The relational triangulation framework sheds some light on the process of how behaviour can be generalised and contextually controlled to enable perspective-taking. Our findings support this idea and show that the relational triangulation framework can be applied more broadly, beyond the visuospatial perspective-taking tasks employed in the original evaluations of this model (Guinther, 2017, 2018). In the current study, only half of the participants demonstrated the contextually controlled derived perspective according to the interpersonal alignment of “same” and “opposite” stimuli. However, the poor performance on the model appeared to be primarily a result of their failure to derive the “same” and “opposite” relations among the stimuli that were used to test the model. The results may have been influenced by insufficient exemplars being provided in the pre-training phase, an application of unconventional stimulus configurations of the arbitrary relations during the training and testing phases, and the possible effect of distractor stimuli. These methodological issues may be examined in future studies. In the continuous effort to clarify the contribution of stimulus (or contextual) control mechanisms to complex behaviour, we believe that the current study offers a small but significant addition to the knowledge related to derived relational responding relevant to perspective taking.

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Appendix A

An Average of the Correct Responses in Deriving SAME or OPPOSITE Relations over the Untrained Stimuli

Experiment 1

Derived stimulus relations	Comparisons	Numbers of times the test blocks being repeated			
		1	2	3	4
SAME/A1 [*A3*, B1, D2]	Correct [A3]	63%	64%	82%	87%
	Incorrect [B1]	28%	23%	15%	16%
	Distractor [D2]	9%	11%	3%	3%
SAME/B1 [*B2*, A3, D1]	Correct [B2]	41%	37%	42%	44%
	Incorrect [A3]	38%	42%	44%	47%
	Distractor [D1]	22%	22%	14%	9%
OPPOSITE/B1 [*A2*, B2, D3]	Correct [A2]	48%	61%	61%	63%
	Incorrect [B2]	40%	26%	26%	26%
	Distractor [D3]	12%	13%	13%	11%
OPPOSITE/B2 [*A1*, B1, D4]	Correct [A1]	36%	51%	53%	54%
	Incorrect [B1]	44%	34%	24%	38%
	Distractor [D4]	20%	13%	24%	8%
OPPOSITE/B2 [*A3*, B1, D3]	Correct [A3]	35%	51%	59%	49%
	Incorrect [B1]	53%	38%	33%	40%
	Distractor [D3]	12%	9%	8%	11%
OPPOSITE/B1 [*A3*, B2, D4]	Correct [A3]	36%	55%	62%	60%
	Incorrect [B2]	43%	39%	28%	28%
	Distractor [D4]	21%	6%	10%	11%

Experiment 2

Derived stimulus relations	Comparisons	Test block
		1
SAME/A2 [*A3*, C1, D2]	Correct	80%
	Incorrect	11%
	Distractor	9%
SAME/A3 [*A2*, C2, D1]	Correct	84%
	Incorrect	11%
	Distractor	4%
SAME/C1 [*C2*, A3, D2]	Correct	51%
	Incorrect	36%
	Distractor	13%
SAME/C2 [*C1*, A2, D1]	Correct	44%
	Incorrect	33%
	Distractor	22%
OPPOSITE/C1 [*A1*, C2, D4]	Correct	47%
	Incorrect	38%
	Distractor	16%
OPPOSITE/A1 [*C1*, A2, D3]	Correct	36%
	Incorrect	36%
	Distractor	29%
OPPOSITE/C2 [*A1*, C1, D4]	Correct	60%
	Incorrect	29%
	Distractor	11%
OPPOSITE/A1 [*C2*, A2, D3]	Correct	58%
	Incorrect	26%
	Distractor	16%
OPPOSITE/C2 [*A3*, C1, D4]	Correct	58%
	Incorrect	33%
	Distractor	9%
OPPOSITE/A3 [*C2*, A2, D3]	Correct	60%
	Incorrect	20%
	Distractor	20%
OPPOSITE/C1 [*A3*, C2, D4]	Correct	60%
	Incorrect	33%
	Distractor	7%
OPPOSITE/A3 [*C1*, A2, D3]	Correct	58%
	Incorrect	24%
	Distractor	16%

Chapter 3

Conceptual manuscript

What can we learn by treating perspective taking as problem solving?[1]

[1] This study was published as a paper with the same title in the journal, *Perspective on Behavior Science, 44,* 359-387, 2021, authored by Tokiko Taylor and Timothy L. Edwards.

Chapter Introduction

Guinther (2017, 2018) proposed the Relational Triangulation (RT) framework, presenting the idea that each perspective is derived through the process of relational responding as defined by relational framing theory (RFT). Guinther demonstrated this using contextually controlled coordination framing. By applying the frame of opposition, I evaluated the utility of the RT framework, and found that it appears to be useful even when applied to non-equivalence conditions. I also tested the utility of the framework without an explicit visuospatial element. The RT framework accurately predicted the derivation of another's perspective when participants demonstrated adequate contextual control by stimuli associated with two given sides of the triangle.

While the RT framework can be applied to explain some basic perspective-taking activity, it may only account for a small slice of perspective-taking behaviour. There are many perspective-taking scenarios that appear to have little to do with relational triangulation or that have additional components that must also be explained. For example, when playing chess, players need to consider their opponents' plans, threats, and previous moves, then decide their next move and general strategy. The functionality associated with the display on the board is always "different" between the players. This type of complex derivation process to predict another person's perspective is always under the contextual control of "different" interpersonal alignment in the RT framework, which is not helpful for the player in regards to predicting what their opponent will do. The RT framework only appears to clarify that the player would respond as if the other player has a "different" perspective, but it does not appear to help to explain the mechanisms underlying specific moves on the chessboard.

Even in cases where the RT framework does appear to be useful, it does not clarify where the relevant stimulus functions have come from. The most rudimentary forms of perspective-taking tasks, such as inferring the preference of another individual, appear to be achieved mainly through conditional discrimination. For example, Repacholi and Gopnik (1997) investigated whether a group of toddlers (aged 14 to 18 months) could accurately infer another person's preference of food items (crackers and broccoli). The children tasted each food item; then an experimenter sat across from the child and tasted both as well, indicating her preference for each by expressing either "Eww!" or "Mmm!" Subsequently, the experimenter requested that the child gave her some more food (e.g., "can you give me some?") by placing her hand in front of her, without any indication or additional cues to indicate her desired item. Thus, the child had to infer the experimenter's preference based on the previous demonstration of the experimenter's response to each food. For the critical test trial, the experimenter indicated her preference for the broccoli, which was different from the child's own (in the experiment, all children preferred the crackers). The 14-month olds offered the crackers to the experimenter[2], but the 18-month olds were able to offer broccoli based on the inference of the experimenter's preference.

The important aspect demonstrated in this study (Repacholi & Gopnik, 1997) is that the 18-month olds were able to discriminate between food that was present when the experimenter made the expression of "Mmm!" and not with "Eww!"[3] It is only speculative, at this point, whether this type of rudimentary perspective-taking task involves relational responding (e.g., self and others' preferences are understood as "same" or "different"), or whether such responding may not be necessary at all. Investigating what behavioural process is involved in the occasion when a simple perspective-taking task develops into something complex might be daunting; however, it is worth examining if the behavioural principles that can explain the simple task can be also applied to solving the complex task. It is evident that the RT framework does not clearly explain all of the underlying functions and activities that set the occasion for a specific relational triangulation event to take place.

The basic processes underlying the RT framework, which operate as a form of conditional-discrimination learning, could include a person engaging in a sequence of behavioural chains that involve different contextual stimuli, or the self-generation of additional stimuli to arrive at the appropriate contingency. For example, when thinking about what to cook for your partner's birthday dinner, you may recall several dishes your partner enjoyed in the past, or you might search through a recipe book. The behaviour you engage in when making a decision about the dinner involves an additional stimulus-discrimination process, one that goes beyond the triangulation model.

[2] The study showed that 68% of 14-month olds failed to comply with the instruction (i.e., did not offer either food items); they may have still been learning to mand or did not understand the verbal request. For the 18-months old participants, the figure for failure of compliance dropped to 30%.
[3] Repacholi and Gopnik interpreted the difference observed in the response from the two groups as a result of having (or not having) the capacity for Theory of Mind.

It is possible that the term “perspective taking,” as well as any other models used to explain the phenomenon, is used mainly to talk about something that is in fact conditional-discrimination learning. As discussed in the previous chapters, the basic operations relevant to perspective-taking tasks appear to involve a participant’s conditional-discrimination learning (e.g., BH protocols can be solved relying solely upon simple stimulus properties of the protocol materials, or by deriving untrained stimulus relations commonly generated by matching-to-sample procedures). Some researchers have demonstrated that there is no difference in the performance of younger children when solving a traditional unexpected transfer task compared to an equivalent conditional discrimination task that did not require any false-belief attribution (Bloom & German, 2000; German & Leslie, 2000; Roth & Leslie, 1998; Slaughter, 1998; Zaitchik, 1990). These studies suggest that what may be required for children to solve some perspective-taking tasks is an ability to recall an event that has happened previously. One such instance is in a false-photograph task, children are asked about what has changed or differs from the current condition of a certain situation. For example, children see a photographer take a picture of an apple hanging on a branch. The photographer then takes about 10 minutes to print out the image. While waiting for the printed image, children see the actual apple fall on the ground. The children are then asked to say what the printed photo depicts. This task does not require any false-belief attribution, but it was designed to have functionally equivalent task components (e.g., recalling behaviour) to the traditional unexpected transfer test (e.g., the Sally-Anne test). Children under 3 years old did not pass the false-photograph test, nor the original Sally-Anne test (German & Leslie, 2000; Slaughter, 1998; Zaitchik, 1990). In another example similar to the one above, Roth and Leslie (1998) assessed whether children could make a distinction between the state of a target object in two conditions: behind and in front of a screen. In one experiment, Boxes A and B were presented to children, and an object was relocated from Box A to B. Both boxes were then placed behind an opaque screen. After hiding the original boxes behind the screen, another set of boxes (A1 and B1) was presented in front of the screen, which had exactly the same appearance as Boxes A and B located behind the screen. This time, an object was relocated from Box B1 to A1. Children were asked which box behind the screen contained the object (i.e., A or B). The test was provided in a context without any social stimuli (i.e., without Sally and Anne equivalent dolls), and examined children's discrimination of both stimuli currently available to them and stimuli presented previously. It was observed that children aged 3 did not pass this test.

The studies and examples above suggest that the underlying behavioural processes responsible for deriving the perspectives of others are fundamentally a matter of stimulus-control processes. While this type of bottom-up approach is not new in the traditional field of behaviour analysis, such as the area of problem solving (Palmer, 1991; Skinner, 1966), it has not been systematically applied to perspective-taking behaviour. Given that the two categories of behaviour overlap significantly, the following manuscript is a conceptual paper exploring an alternative interpretation, which is to understand perspective taking as a type of problem-solving behaviour.

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ORIGINAL RESEARCH

What Can We Learn by Treating Perspective Taking as Problem Solving?

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Abstract
Perspective taking has been studied extensively using a wide variety of experimental tasks. The theoretical constructs that are used to develop these tasks and interpret the results obtained from them, most notably theory of mind (ToM), have conceptual shortcomings from a behavior-analytic perspective. The behavioral approach to conceptualizing and studying this class of behavior is parsimonious and pragmatic, but the body of relevant research is currently small. The prominent relational frame theory (RFT) approach to derived perspective taking asserts that "deictic framing" is a core component of this class of behavior, but this proposal also appears to be conceptually problematic. We suggest that in many cases perspective taking is problem solving; when successful, both classes of behavior involve the emission of context-appropriate precurrent behavior that facilitates the appropriate response (i.e., the "solution"). Conceptualizing perspective taking in this way appears to have many advantages, which we explore herein.

Keywords deictic framing · mind reading · precurrent behavior · stimulus control · theory of mind · visual perspective taking

Perspective taking is an ability of critical importance that helps us establish and maintain relationships, negotiate deals, predict the actions of others, and achieve a wide variety of other valuable outcomes. This ability has been studied extensively by psychologists, who have approached the topic using many different theoretical constructs and experimental procedures. In this work, we present some common theoretical and experimental approaches to perspective taking, followed by a description of a behavioral approach to perspective taking and problem solving. In brief, problem solving relies on the emission of overt or covert behaviors that produce supplementary stimuli that in turn evoke

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behavior that may produce the reinforcer (i.e., a solution to the problem). Problem-solving behavior is evoked in contexts in which a discriminative stimulus (S^D) associated with a reinforcer is present, but the response that is required to obtain the reinforcer cannot be emitted directly. Because much perspective-taking behavior, including behavior in experiments designed to study this class of behavior, appear to qualify as problem solving, we make the case that behavioral theory that has been developed for the purpose of understanding problem solving can serve as a strong foundation for understanding perspective taking. A variety of assessments and tasks are used to study perspective taking. These can be roughly divided into two categories: those focusing on visual perspective taking (VPT), and those focusing on mental state attribution, typically referred to as theory of mind (ToM).

Visual Perspective Taking

VPT tasks include spatial components, such as the current position of a subject (viewer), the target (an experimenter, a doll, or another person), and the position of other objects in relation to the subject and the target. VPT is often subdivided into Level 1 and Level 2 (Flavell et al., 1980, Flavell et al., 1981; Flavell, 2004; Moll & Meltzoff, 2011). At Level 1, a subject demonstrates the ability to differentiate the perspectives of self and others based on what can be seen by each party. For example, a two-sided card with a different picture on each side is held up between a child and a teacher, and the child is asked, “What can you see, and what can I see?” Children are also assessed for their VPT Level 1 ability using tasks based on line-of-sight paradigms. In one relevant experimental protocol, researchers placed a doll on one side of a cardboard screen and a desk on the same side as the doll, or the opposite side, and asked children to indicate whether the doll could see the desk (Leslie & Frith, 1988). In another relevant study, Baron-Cohen (1989) examined whether preschool children could identify which object an experimenter was looking at, when only the experimenter’s gaze (not head orientation) was available as a cue.

Although VPT Level 1 tasks are meant to reveal the participant’s ability to identify *if* others’ perspectives differ, VPT Level 2 tasks are meant to reveal the participant’s ability to identify *how* others’ perspectives differ from their own. In one relevant task, the researcher places a card with a picture flat on a table between the participant and the researcher. The participant is then asked, for example, “When I look at the picture, is the turtle the right way up or upside down?” (Flavell et al., 1981, p.101). The three-mountain task is a VPT Level 2 task that assesses the participant’s ability to determine how perspectives differ based on a vantage point in a scene based on selection of pictures that correspond with specific vantage points. The reality–appearance distinction task is also said to provide information about Level 2 perspective taking. In one such task, the researcher gives a child a sponge that appears to be a rock. The child is first asked what the object looks like and then asked, “is it really and truly a sponge or is it really and truly a rock?” The child’s ability to discriminate between what an object appears to be at first sight and what it really is (e.g., a sponge that looks like a rock or a candle that looks like a pencil) is considered evidence of VPT Level 2 ability, which is correlated with the ability to distinguish between appearance for the self and appearance for another person (Flavell, 1986; Starr & Baine, 1996; Moll & Meltzoff, 2011).

VPT is also evaluated using spatial tasks that measure one's understanding of how objects in the environment are oriented in relation to one another (e.g., behind, below, to the right of). From one's own perspective, this type of task is relatively straightforward, but tasks involving identification of the relative positions of objects from another perspective are less so. One potential strategy for solving such tasks is "egocentric mental rotation," which involves imagining the perspective of another person or point of view (Kessler & Thomson, 2010; Michelon & Zacks, 2006; Surtees et al., 2013). Object rotation is another possible strategy that involves imagining the movement of an object relative to the viewer and the environment. A variety of studies have been conducted to understand the conditions under which participants engage in object rotation or egocentric mental rotation when completing this type of VPT task. For example, Michelon and Zacks (2006) asked participants to identify whether an object was to the left or to the right of a doll. They found that the response latency increased with an increase in the angular distance between the participant's and the doll's orientation, which they interpreted as evidence for participants applying egocentric mental rotation under these conditions.

Theory of Mind

The second general category of perspective taking, typically referred to as theory of mind (ToM), emphasizes the role of mental attribution in perspective taking. Originally proposed by Premack and Woodruff (1978), ToM refers to one's ability to differentiate their own perspective from the perspectives of others by making inferences about others' informational states (i.e., thoughts and feelings). This general ability is also sometimes referred to as "mind reading" (Howlin et al., 1999). A broad variety of tasks have been developed with the intent of revealing participants' ToM capabilities.

Unexpected transfer or identity tasks are meant to reveal one's ability to identify "false beliefs" held by another individual. The most well-known ToM task of this variety is the Sally–Anne test (Baron-Cohen et al., 1985), which was introduced by Wimmer and Perner (1983). In this false-belief task, a child is introduced to a vignette, such as, "Sally and Anne were in the room. Sally was playing with her marble, then placed it in her basket and left the room. Anne then put it into her basket. Later, Sally comes back to the room to play with her marble." The child is asked questions such as, "Where does Sally think her marble is?" to see if the child can identify the false belief held by Sally. There are many variations of this test. The unexpected identity task is another test developed to measure a child's ability to identify a false belief. In the task, an examiner shows the participant a container for an object (like a sweets packet), but the container actually holds another object (e.g., a pencil). After the participant opens the container and acknowledges what is inside (e.g., they say that they see a pencil), a doll is introduced to the child. The child is given a prompt, such as, "Here comes Rosie. What will she think is inside?" The unexpected identity task is similar to the appearance–reality test because both assess a child's ability to distinguish two identities of the same object (e.g., a sponge that looks like a rock or a candy box that contains pencils), but the unexpected identity task focuses on another person's false belief prior to their exploration of the object.

Picture sequencing is used to test a participant's understanding of typical causal outcomes, including those involving people engaging in various activities, and is meant to provide an indication of a participant's ToM capability (Baron-Cohen et al., 1986). Some sequences focus on interactions among people (e.g., a child crying over his ice cream being snatched) or violations of someone's expectations (e.g., someone being surprised about a missing item). The experimenter provides the first picture, then asks the participant to look at the other pictures and arrange them into the correct sequence; the participant is then asked to narrate the story.

The "reading the mind in the eyes test" was developed as a measure of "advanced" ToM ability in high-functioning adults with autism or Asperger syndrome (Baron-Cohen et al., 1997; Baron-Cohen et al., 2001). This test requires a subject to match a term to a picture of eyes without any other contextual information provided. For example, the subject selects a correct term (e.g., "serious") from the other choices, such as "ashamed," "alarmed," and "bewildered." Another measure of advanced ToM abilities known as the "faux-pas test" assesses the ability of both children and adults to identify socially awkward behavior using 20 short stories, each containing a faux pas incident (Baron-Cohen et al., 1999; Stone et al., 1998). A similar task is also used to measure one's comprehension of others' mental states in different situations, such as persuasion or a white lie, and to make inferences about the characters' thoughts, feelings, and intentions (Happé, 1995). Hutchins et al. (2008) developed an assessment battery that combines various ToM tasks, the ToM task battery inventory (ToMI). It includes items assessing inferences about emotions and beliefs in addition to basic false-belief tasks such as the Sally–Anne test. Howlin et al. (1999) developed a teaching guideline for children with ASD to improve their "mind-reading" ability, combining different ToM tasks ranging in complexity from simple visualization tasks to more complex false-belief tasks used in the various ToM studies for children.

There are also interview-based assessment tools for measuring ToM. The "theory of mind assessment scale" (Th.o.m.a.s) is a qualitative tool developed especially for individuals with schizophrenia (Vallana et al., 2007). It consists of 39 open-ended questions investigating the interviewee's understanding of their own and others' perspectives (e.g., "Do you notice when others feel good?" "Do others notice when you feel good?"). The interpersonal reactivity index (IRI) questionnaire is used in many perspective-taking studies to measure attitudes in perspective-taking (Galinsky et al., 2008; Van der Graaff et al., 2014; Vilardaga et al., 2012; Barbero-Rubio et al., 2016; Kavanagh et al., 2018). It contains nine items for assessing the test taker's "spontaneous" perspective-taking ability (e.g., "When I'm upset at someone, I usually try to 'put myself in his shoes' for a while"), indicated using a scale from "strongly disagree" to "strongly agree." One issue with interview-based ToM measures is that they rely upon self-report and, therefore, outcomes may not correspond with behavioral measures of perspective taking.

The search for evidence of ToM extends to studies with nonhumans and infants as well, and tasks without an explicit language requirement have been developed for this purpose. In the anticipatory looking test, a subject's eye movement and duration are recorded by an eye tracker while the subject watches a series of short video clips showing actors (e.g., a human or a doll) performing false-belief tasks. In general, the experiment starts out with a "familiarization" procedure in which a subject is shown video footage demonstrating that a target object (e.g., a toy) is hidden in one of two locations. Then, the actor searches for it in its true location, where the target object was hidden. This is followed by a second video showing a false-belief component in which the object is relocated from one location to another while the actor is absent from the scene. When the actor returns to the scene, the initial direction and duration of the participant's gaze are recorded and used to draw conclusions about where the participant predicts the actor will look for the toy (Krupenye et al., 2016, 2017; Onishi & Baillargeon, 2005; Senju et al., 2011; Southgate et al., 2007).

The Guesser-Knower task was also developed to reveal information about a participant's ToM abilities. In this task, a participant sees two actors, a "knower" who has access to information about the location of a target (typically food) and a "guesser" who does not. For example, in a "guesser-absent" probe trial, the guesser leaves the experimental room, and the knower remains in the room while a baiter puts food into one of two food containers. The participant's view of the containers, however, is occluded, so they cannot see where the food was placed. Upon the guesser's return, the guesser and knower pose in the same manner but point and/or gaze at two different containers. The participant is then allowed to approach one of the containers. Approaching the container referenced by the "knower" is typically interpreted as evidence of ToM (Povinelli et al., 1990). Other versions of this task have been used, including tasks in which the guesser simply looks away while the food is being placed, and several species have been tested, including dogs (Catala et al., 2017; Maginnity & Grace, 2014) and scrub jays (Emery & Clayton, 2001). In a related task, researchers tested chimpanzees' and human infants' ability to predict the actions of others wearing opaque versus translucent goggles (Karg et al., 2015; Meltzoff, 2007; Meltzoff & Brooks, 2008; Senju et al., 2011; Vonk & Povinelli, 2011).

Another approach to testing ToM ability in nonhumans is to see whether they approach forbidden food (e.g., in situations where a human instructs a dog not to eat a piece of food on the ground). Various conditions can be set up to test an animal's performance. For example, Bräuer et al. (2004) compared dogs' tendency to approach the forbidden food when their owner's view was blocked by a barrier and when it was not. Other variations of this task have also been tested, including conditions in which the human observer is blindfolded or simply looking away rather than obstructed by a barrier (Bräuer et al., 2004; Kaminski et al., 2009). If the participant is more likely to take food when the observer's view is obstructed, this is interpreted as evidence of ToM (Anderson et al., 1995; Anderson et al., 1996; Povinelli et al., 1996). In another type of study, called a begging task, if subjects approach and beg from a "seer" (whose view is not obstructed and who is capable of delivering food) more readily than a "blind" experimenter (whose view is obstructed or who is otherwise unable to respond to the participant's begging), the participant is said to be demonstrating ToM (Udell et al., 2011).

Perspective Taking Controversy

There are many other tasks that have been used to study VPT and ToM. Our aim in providing descriptions of some of the commonly used tasks is to paint a picture of the conditions under which researchers consider behavior to be demonstrative of "perspective taking" or ToM. Although we have grouped these tasks according to the theoretical construct (VPT or ToM) that they are most closely associated with in the literature, there is some inconsistency in the literature regarding which construct a task is most relevant to. For example, the reality–appearance distinction task and the unexpected identity task are similar but are associated with two different constructs. There is also considerable disagreement about whether these two constructs have a "common cognitive denominator" (Moll & Meltzoff, 2011; Andrews et al., 2003; Andrews et al., 2012) or whether VPT and ToM are unique abilities. ToM tasks are typically more "conceptual," often involving storytelling, story comprehension, and reporting of emotions (Aichhorn et al., 2006; Flavell, 1986; Gopnik & Astington, 1988), whereas VPT tasks are more commonly spatial tasks, but there are many exceptions to these general rules regarding the type of tasks used to study each construct (e.g., the guesser-knower task does not seem to fit the description of a typical ToM task). The face-value suitability of these tasks for studying each construct appears to be the sole consideration underlying the development of most perspective-taking tasks, which is problematic not only because constructs such as ToM are loosely defined, but also because the intentions of the task designer appear to heavily influence the interpretation of the outcomes obtained from the tasks.

These and other issues associated with ToM measures and the interpretation of study outcomes have been raised in the context of researching ToM in nonhumans. Penn and Povinelli (2007) critically evaluated the evidence that has been produced regarding ToM in nonhumans and concluded that none of the experimental protocols that have been used for this purpose are capable of distinguishing between "mind reading" (i.e., ToM) and "behavior reading" (i.e., stimulus control). Van der Vaart and Hemelrijk (2014) reviewed the evidence associated with this and other criticisms of research on ToM in nonhumans and concluded that Penn and Povinelli's conclusion is "irrefutable." In addition, van der Vaart and Hemelrijk found that many of the reviewed studies lacked appropriate control conditions and that the researchers frequently demonstrated a strong bias favoring ToM interpretations, even in the face of weak or conflicting evidence. For example, in studies employing the begging task with apes, van der Vaart and Hemelrijk found that researchers often emphasized evidence that supported ToM explanations and ignored evidence that did not. In studies examining recaching behavior in scrub jays and Clark's nutcrackers when other birds are present, opposite outcomes related to the importance of line of sight between the observing bird and the cache were both interpreted as favoring a ToM explanation.

Some researchers have suggested that mind-reading-based interpretations of the outcomes of these studies are *more* parsimonious than behavior-reading explanations (Emery & Clayton, 2008; Tomasello & Call, 2006) but others have pointed out that predicting the actions of others based on representations of internal states in others is much more complex than predicting their actions based on observable stimuli (Barrett, 2010; Penn & Povinelli, 2007; Shettleworth, 2010; van der Vaart & Hemelrijk, 2014). Penn and Povinelli (2007) made some recommendations for protocols that might be used to evaluate ToM in nonhumans, including tasks for chimpanzees that are similar to the Sally–Anne task in which the location of a food item may be changed in the presence or absence of a dominant chimpanzee. The added complexity, however, does not eliminate the possibility for "behavior reading" explanations of success in these tasks. Van der Vaart and Hemelrijk (2014) were confident that adding such complexity would result in task failure, because chimpanzees regularly fail to "demonstrate ToM" in simpler tasks. Furthermore, failure in such a task would lead to no conclusive interpretations with respect to ToM. Penn and Povinelli rejected the notion that their criticisms apply to the protocols that have been used to study ToM in humans, but to support this point, they simply referred to the volume of ToM literature. Shettleworth (2010) and Barrett (2010) suggested that humans *can* intuit unobservable states in others but that we rarely do. That is, much of human perspective taking that is attributed to "mind reading" (i.e., ToM) is actually "behavior reading."

We suggest that these critics are on the right track but that the murky nature of the "ToM" concept has complicated the task of exploring the mechanisms that give rise to specific examples of perspective taking and scientifically evaluating perspective taking in humans and other species in general. The topic of ToM is entangled with topics of concern that are fundamental to general psychology, including concerns about the subject matter of psychology itself and the role of folk psychology explanations in the field of psychology. Behavioral explanations for perspective taking are viewed by some psychologists as "killjoy" (Heyes, 1998; Shettleworth, 2010) explanations that lead to "despair" (Tomasello et al., 2003), but behavioral explanations are undoubtedly the starting point for a scientific understanding of perspective taking and must be exhausted before alternative explanations can be considered if we are to abide by the parsimony principle. Moreover, the behavioral approach to perspective taking is not limited to exploration of perspective taking behavior that can only be directly controlled by stimuli that are present in the immediate environment (i.e., "behavior reading). A wide range of behavioral theory and experimental tools have been developed to account for (and change) the type of behavior that is involved in "mind reading" or "ToM" explanations of perspective taking, including conversing, thinking, and imagining. The functional approach that characterizes behavioral psychology offers valuable insight into perspective taking that can be translated into effective applications. We now explore the behavioral approach to perspective taking before presenting our main hypothesis regarding the potential value of treating perspective taking as behavior analysts treat problem solving.

Perspective Taking: The Behavioral Approach

The behavior of participants in perspective-taking tasks and in everyday perspective-taking scenarios can be evaluated using the methods and principles of behavior analysis. This approach to understanding perspective taking is parsimonious and pragmatic, but it has yet to receive broader recognition among scientists and practitioners studying perspective taking. Behavioral interpretations of findings from VPT tasks are not necessarily at odds with general psychology interpretations, but interpretations that refer to poorly defined hypothetical constructs are not compatible with the behavioral approach. The most common such explanation for perspective-taking behavior, ToM, is a patent example of a loosely defined hypothetical construct. Schlinger (2009) described ToM as a "meme," and Baum (1998) suggested that looking for ToM is no different from looking for the "soul." Depending on how one defines the soul or ToM, it may be discovered, or not, in any individual. Moreover, the ToM concept leads to circular reasoning: observing certain behavior in an individual causes some researchers to conclude that they "have a ToM" and when asked why this behavior has been emitted they may explain that it is because they "have a ToM" (Schlinger, 2017).

Of course, there is a definition attached to the label: ToM refers to an individual's belief that another individual has their own thoughts, beliefs, and feelings (i.e., another perspective), but this does not lend any clarity to the concept. For instance, when searching for evidence that apes "have a ToM," researchers are asking a question like, "does this ape believe that people or other apes have their own thoughts, beliefs, and feelings?" This begs the question, what does it mean to "believe" that another individual has their own private thoughts. Is this process not dependent upon advanced language capabilities (Gordon, 1998; Gray & Russell, 1998)? Even if it were possible to conclusively determine that an individual has ToM, because we cannot begin to understand what this means, how could this information benefit anyone?

In contrast, the behavioral approach to perspective taking involves, first, identifying the behaviors of interest (e.g., the behaviors that lead some researchers to conclude that an individual has a ToM); second, investigating the present stimulus conditions and the learning history that is responsible for the emission of such behavior. A social construct such as ToM cannot be the cause; the cause is to be found in the biology and the environment of the organism. Statements (whether overt or covert) about what others think and feel are not ultimate causes of perspective taking behavior, though they may play a part in the process of perspective taking. Instead, these behaviors are a type of perspective taking behavior that must also be explained. Evidence for perspective taking (including ToM) has come from a variety of tasks, some of which do not have any verbal[1] component (especially those used for very young children and nonhumans) and others that are partially or entirely reliant on the verbal ability of the participant. We will briefly examine fundamental behavioral processes that must contribute to all perspective taking tasks and then review some higher order processes that are relevant to the causes of behavior in perspective taking tasks with a verbal component.

Perspective Taking: Fundamental Behavioral Processes

The key to understanding performance in any perspective taking task lies in an understanding of stimulus control. Unless the experimenter has presented an unsolvable problem, all of the stimuli that are required to evoke a correct response will be present in the task, assuming that the individual who is participating in the task has the appropriate biological constitution and learning history to respond appropriately to those stimuli. Failure to respond accurately in any perspective-taking task will necessarily be the result of a deficit in the stimuli that are present or a result of those stimuli not having the necessary functions. Of course, stimuli may be "present" but not accessed by the participant (e.g., they may have looked away during a critical stimulus change) and the functions of the stimuli in the task may be temporarily altered by motivating operations (Edwards et al., 2019a, 2019b).

Stimulus control can be simple, as when a discriminative stimulus evokes a response that has historically been reinforced in its presence. However, and this is particularly relevant to perspective-taking tasks, the evocative functions of discriminative stimuli can be conditional upon the presence of other stimuli. For example, an infant's

[1] Skinner (1957) defined verbal behavior as behavior for which reinforcement is mediated by others whose behavior has specifically been conditioned to do so. Although some have found this definition unsatisfying (e.g., Hayes et al., 2021), we will apply it herein unless otherwise specified.

interaction with a specific toy is more likely to be reinforced (e.g., by joint play and attention from an adult) if the adult is looking at or pointing at the toy. As a result, the toy becomes a more effective evoker of relevant interaction when the adult's gaze is directed toward the toy (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991; Gewirtz & Pelaez-Nogueras, 1992; Pelaez et al., 2012). Conditional stimulus control emerges from the conditional nature of relationships among events in the environment and learning mechanisms that are sensitive to such relationships. In experimental tasks designed to evaluate perspective-taking abilities, the correct response depends on which sequence of stimulus changes the participant has been exposed to. For example, in the guesser/knower task, identification of the "knower" is conditional upon the presence of stimuli that would result in them "knowing" (e.g., the placement of an object in the same direction as their gaze). In this well-studied task, we can be sure that there is no stimulus deficit. Therefore, if a participant fails the task, after addressing attentional and motivational factors, a behavioral researcher would conclude that the failure must be a result of deficiencies in the individual's history of learning with those stimuli or, as a last resort, biological constraints on the individual's ability to learn to respond appropriately to those stimuli.

A critical aspect of stimulus control that must be considered is stimulus generalization, the control of behavior by stimuli that are formally similar to but not the same as stimuli that were present when learning took place. The stimuli that control behavior in the present environment will necessarily differ from those that were present during conditioning in the past, so stimulus generalization is an essential feature of any learning mechanism. Stimulus generalization within a dimension (e.g., wavelength) can be quantified and, with additional training, stimulus generalization can be increased or decreased (Ghirlanda and Enquist, 2003). In the guesser/knower task, a successful participant will have had experience with people looking at objects being placed in occluded places and then going to those places to retrieve those objects, but the specific stimulus features of the people, places, and objects will have varied. Even though the specific stimuli and people used in the task differ from the many specific stimuli to which the individual has been exposed previously, they may still evoke the correct response. Failure to respond "correctly" in a guesser/knower task by a participant that appears to have an appropriate learning history could be a result of insufficient stimulus generalization.

Applying the parsimony principle, these fundamental and well-established behavioral processes must be considered before behavioral scientists consider other potential explanations for success or failure in perspective-taking tasks of all types. Failure to understand stimulus control mechanisms can lead to the erroneous conclusion that participants in a study do not demonstrate stimulus control when successfully completing a perspective-taking task. For example, Krupenye et al. (2017) conducted a follow-up experiment to test Heyes's (2017) suggestion that apes who successfully completed ToM tasks in their original experiment (Krupenye et al., 2016) did so because of fundamental stimulus control mechanisms rather than through social cognitive (ToM) mechanisms. To test this hypothesis, Krupenye et al. (2017) replaced the original ape-like stimuli (humans in ape costumes) used in their original study with arbitrary, inanimate shapes (a triangle and a semi-circle) and observed the apes' tendency to look in the location where one arbitrary shape last "saw" an object hidden. Of those apes attending to one of the two hiding places, 14 out of 22 (64%) attended to the “correct” location (where an actor, the shape in this instance, should falsely believe that the object was hidden) in the follow-up study compared to 17 out of 22 (77%) in the original study. Krupenye et al. (2017) concluded that these results suggest that stimulus-control mechanisms cannot explain apes’ ability to accurately complete such tasks. This conclusion, however, demonstrates a fundamental misunderstanding of how stimuli come to control behavior.[2] The apes in this research, raised in the Wolfgang Kohler Primate Research Center, had intensive exposure to humans and other apes across their lifespans and, therefore, many examples of what humans and apes tend to do in specific contexts (including looking for things where they last saw them). The apes’ exposure to the arbitrary stimuli used in Krupenye et al. (2017), however, was limited to two familiarization trials prior to the critical tests. It is not surprising that many of the apes would not behave as if the arbitrary shape would “look for” a hidden object; these shapes differ substantially from humans and apes and, therefore, generalization should not be expected to occur to these stimuli. With no specific conditioning history, this type of study is completely inadequate for testing the stimulus control hypothesis.

Perspective Taking: Verbal Processes

Much of the behavior that we refer to as “perspective taking” is verbal in nature, but the fundamental principles outlined above do not cease to apply in such cases. If, for example, we want to understand why an observer says that a young boy who dropped his ice cream cone on the ground is “sad,” we must consider the current stimulus situation and the observer’s learning history associated with similar stimuli. Skinner (1957) provided a coherent theoretical account of how we learn to describe “private” events, those events that can only be directly experienced by one individual, such as the events that we learn to call a “stomachache” or “sadness.” According to Skinner, the individual’s community teaches them to “tact” (i.e., make a verbal response in the presence of) their own private experiences using public accompaniments to private stimuli. For example, a father who sees that his child has bumped her head and is crying (public stimuli) will often emit “tacts” (e.g., “that hurts”) related to the private events that the child is likely experiencing and reinforce “echoics” (i.e., repetition of the verbal statement, “that hurts”), which eventually leads to unprompted tacts by the child under similar circumstances. Through stimulus generalization or other processes (see below), the child may also learn to describe private events that do not have any public accompaniment. For example, she may learn to tact burning sensations from instances where she has been burned from touching something hot or caustic and then apply this tact when she feels a similar sensation internally but without any accompanying public stimuli. The child’s verbal community also reinforces their tacting of public accompaniments of private events in others. For example, when a child’s father stubs his toe, grimaces, and holds his foot, a variety of responses (e.g., “ouch,” “owie,” “hurts”) are likely to be modeled and reinforced.

[2] This conclusion is also based on a small difference in the outcomes between the two studies, and 5 of 22 apes (23%) failed to identify the correct location in the original study using ape-like stimuli. Therefore, these conclusions may also be demonstrative of the commonly observed bias in favor of ToM-based interpretations that we discussed previously.

An understanding of stimulus equivalence can enrich our understanding of complex verbal behavior (Guinther & Dougher, 2015), including its symbolic nature, and can shed light on the processes that lead to one's ability to accurately tact private events to which only another person has direct access (Spradlin & Brady, 2008). Words such as "stress," "anxiety," and "worry" participate in stimulus classes with certain facial expressions and with behavioral patterns such as fidgeting and pacing. Observing these behaviors in others (e.g., seeing someone pacing and fidgeting) is likely to evoke one or more of the words that participate in this class of stimuli. Hearing one of the words (e.g., "I am stressing about. . . .") is likely to lead to predictions about these and other related behavioral patterns (e.g., we might predict that they are having trouble sleeping). A child who learns to call a syringe a "syringe" may experience the stimuli associated with an injection and may also learn to tact these stimuli as "painful." They may later learn that a "syringe" is also called a "needle." If they are told that a lancing device for a blood test contains a needle, even if they have never had experience with the device and cannot see the needle or any blood, when seeing someone else using the lancing device, they may respond in accordance with the other person's experience. Although the device was never directly paired with "painful" stimuli, and relevant tacts were not emitted and reinforced in the presence of those stimuli, when seeing someone else getting a blood test, the child may say that it is "painful" and also experience private, respondent behavior similar to the behavior that was elicited when they received an injection (Dougher et al., 1994; Rehfeldt & Hayes, 1998; Roche & Barnes, 1997; Valverde et al., 2009).

In addition to this type of "training" to respond to private events, children are also trained using specific narrative strategies, such as "How would you feel if your cat ran away?" Culture-consistent responses are typically prompted and reinforced. Spradlin and Brady (2008, p. 348) suggest that the ability to predict the behavior of others comes from three types of prior observations and descriptions: "1) Observation and descriptions of the behavior of a specific individual in similar situations; 2) Observation and descriptions of the behavior of many different people in similar situations; 3) Observation and descriptions of one's own behavior in similar situations." By taking this explicit perspective-taking training, relevant general training, and behavioral processes such as stimulus generalization and stimulus equivalence into account, we can develop and test explanations for complex verbal perspective taking without resorting to fuzzy constructs such as ToM.

Perspective Taking and RFT

Some researchers have emphasized the importance of the distinction between self and others in perspective taking and have suggested that this distinction is the basis for our ability to do perspective taking. According to Hayes (1984), "additional arbitrary contingencies" are required to perform perspective taking; the reporting of experiences must be from the locus of I or you, here or there, and now or then. For example, in the statement "I played soccer when I was young, but I play tennis now," the "I" is constant through time even though our physical body changes. According to Hayes, this verbally[3] constructed notion of the consistent locus of the speaker is a core component

[3] Verbal behavior is defined within RFT as "the action of framing events relationally" (Hayes et al., 2001, p. 43; see also Barnes-Holmes et al., 2000).

of perspective taking. These context-dependent words (e.g., “you,” which is only reliably effective if accompanied by other stimuli, such as the gaze of the speaker falling on a specific person) are referred to as “deictic” words in linguistics. Therefore, some researchers working within the RFT framework have dubbed this type of relational behavior “deictic framing” and have identified it as a unique “relational frame” (Barnes-Holmes et al., 2001; McHugh et al., 2004). As we will discuss shortly, this theoretical approach is problematic, but researchers have developed and tested an intervention based upon this theoretical foundation.

This perspective-taking protocol, developed by McHugh et al. (2004; sometimes referred to as the “Barnes-Holmes protocol”), consists of a list of 62 task items involving deictic components. There are three levels of complexity in the protocol: simple, reversed, and double-reversed. In the simplest trial type, the participant just needs to identify information provided in a sentence. For example, they are told, “I have a red brick, you have a green brick.” Then they are asked, “What do I have? What do you have?” In a reversed task, a conditional statement such as, “If I were you and you were me,” is provided in addition to the simple task statement, so the correct answer would be “I have a green brick” and “you have a red brick” when applied to the previous simple task example. Lastly, the double-reversed task involves another reversal as in the following example: “I am sitting here on a black chair and you are sitting there on a blue chair, if I were you and you were me and here were there and there were here, where would you be sitting?” The correct answer is “the blue chair.”

The Barnes-Holmes (BH) protocol has been used in various empirical investigations for assessing and training typically and atypically developing children (Davlin et al., 2011; Heagle & Rehfeldt, 2006; Montoya-Rodríguez & Cobos, 2016; Weil et al., 2011) and adults (Hooper et al., 2015), including those considered to have deficiencies in perspective-taking ability, such as individuals with autism (Barron et al., 2018; Belisle et al., 2016; Gilroy et al., 2015; Gómez-Becerra et al., 2007; Jackson et al., 2014; Lovett & Rehfeldt, 2014; Rehfeldt et al., 2007; Tibbetts & Rehfeldt, 2005), individuals with Down syndrome (Montoya-Rodríguez et al., 2017), social anhedonia (Vilardaga et al., 2012; Villatte, Monestès, McHugh, & i Baque, E. F.,, & Loas, G., 2010a), schizophrenia (O’Neill & Weil, 2014; Villatte, Monestès, McHugh, & i Baqué, E. F.,, & Loas, G., 2010b), and social anxiety disorder (Janssen et al., 2014).

In addition to performance on the protocol items, some researchers have measured the effects of the training on performance in other perspective-taking (i.e., ToM) assessments. So far, little evidence for the effectiveness of training with the BH protocol for improving performance in other ToM tasks exists (Jackson et al., 2014; Lovett & Rehfeldt, 2014; Montoya-Rodríguez & Cobos, 2016; O’Neill & Weil, 2014; Rendón et al., 2012; Weil et al., 2011). For instance, Jackson et al. (2014) found that none of their participants (five children diagnosed with autism) showed improved ToM scores according to the Baron-Cohen model after BH protocol training. In two experiments involving typically developing children, none of the six participants in one study (Montoya-Rodríguez & Cobos, 2016) and only one of three participants in the other (Weil et al., 2011) demonstrated improvements on other ToM tasks following training with the BH protocol. In contrast, O’Neill and Weil (2014) found that three participants diagnosed with schizophrenia who were exposed to Barnes-Holmes protocol training showed improved performance in a hinting task that was designed to assess ToM impairments. However, interpretation of results from studies evaluating the influence of the BH protocol training on ToM task performance is complicated by the finding that language skill level is positively correlated with ToM task performance in children with autism (Gómez-Becerra et al., 2007; Steele et al., 2003). When the BH protocol is effective, is this simply a function of training with complex sentence structures?

Guinther (2017) pointed out a major theoretical issue with the concept of deictic framing: deictic frames do not appear to have any of the key properties of a relational frame as defined within RFT. According to RFT, relational framing is demonstrated through mutual entailment, combinatorial entailment, and transformation of stimulus functions among stimuli participating in the relevant relational frame (Hayes et al., 2001). In line with Guinther's observation, we have been unable to identify any mutual or combinatorial entailment associated with "deictic frames" without reference to other relational frames. As a result, it is also unclear how stimulus functions would be transformed among the stimuli participating in such a frame. By examining how these deictic "relational" stimuli (i.e., putative C_{rel}) have been used in the BH protocol, it is readily apparent that they are not relational stimuli but rather stimuli that can participate in other relational frames (or simply in stimulus equivalence classes). For example, "if I were you and you were me" involves an "if-then" frame and a frame of coordination. The stimuli "I" and "you" can be replaced with "Jim" and "Sally" or "the cabbage" and "the toothpick" without altering the nature of the task. The correct response, emission of one of the arbitrarily selected stimuli (e.g., the "deictic" stimuli in the original task), is determined by other relational (i.e., conditional) stimuli in the prompt. In our own (unpublished) research, we have found that similar results are obtained from a BH protocol task with deictic words and from the same task with nondeictic words. Other researchers have also modified the BH task by replacing the deictic terms with nondeictic terms, such as "yellow" and "orange" (Heagle & Rehfeldt, 2006) or "Cinderella" and "Sponge Bob" (Davlin et al., 2011; Gilroy et al., 2015), obtaining similar results in training and generalization probes as compared with results obtained in other studies implementing the original BH protocol.

Guinther (2017, 2018) proposed an alternative RFT account of derived perspective taking, the relational triangulation framework, which does not appeal to deictic relational frames, and he produced evidence in support of this account with a novel experimental task. In the first study, a demonstration of derivation of others' "true beliefs," seven of eight participants displayed derived coordination of the perspectives of self and others following training to establish contextually controlled "pointing" responses in relation to an observer. In the second study, analogous to the Sally–Anne task, following initial exposure to a scene in which a figurine could "see" a target item in a specific location, the target was then switched while the figurine's "view" of the target was obstructed. Correct derivation of the "false belief" of the figurine involved responding in accordance with the target's original location, from the figurine's perspective. Some participants required additional training to derive "false beliefs" under testing conditions whereas others responded accurately without any additional training.

In a recent review of the BH protocol undertaken by proponents of the BH protocol, Guinther's research was acknowledged, but his criticisms of the BH protocol were not addressed or even acknowledged (Kavanagh et al., 2020). The self-other distinction is not trivial, but distinguishing between self and others is only one of many prerequisite skills involved in perspective taking. In addition, the "deictic framing" approach to understanding this prerequisite behavior appears to be unsound. In our view, further research on the BH protocol is unlikely to significantly improve our understanding of perspective taking. If RFT has something to offer with respect to our understanding of perspective taking, we believe that this will be proportional to its contribution to our understanding of problem solving and the functions of stimuli associated with perspective-taking scenarios.

Problem Solving

A problem can be defined as a situation in which: (1) a discriminative stimulus associated with the availability of a specific reinforcer is present but (2) at least one mediating response is required before the response that produces the reinforcer can be emitted; some also add: (3) the specific sequence of responses that are required to produce the terminal reinforcer have not been reinforced in the presence of the discriminative stimulus (i.e., simple behavioral chaining is excluded; see Holth, 2008; Skinner, 1963, 1966, 1984; Epstein, 1987, 1991, 2008). Using this description, or variants thereof, we can distinguish between examples of problem-solving behavior and nonexamples, which consist of behavior that can be emitted and reinforced with the terminal reinforcer directly in response to the current stimulus conditions. For example, when you cannot find your car key or cannot open the lid of a pickle jar, you have a problem because the behavior that is required to produce the reinforcing outcome, "key in hand" or "jar opened," cannot be produced. These would not be problems if the car key was hanging on its hook or the pickle jar could be opened by simply twisting it as usual. The combination of the discriminative stimulus for the terminal reinforcer and the "problem" stimuli serves as a compound or conditional discriminative stimulus that evokes the mediating behavior. For example, you are dressed to go to work, the clock reads "8:10," and the key hook is empty; this stimulus combination reliably evokes a search for the car key. Depending on the specific features of the problem-solving context, different classes of mediating behavior are likely to be emitted (Holth, 2008). For example, recalling where you recently placed the pickle jar is not likely to bring you closer to opening it, but recalling where you recently placed your car key is likely to lead to locating the key. The general class of problems involving a missing item evoke a related class of behaviors that have been reinforced by finding missing items. Because problem-solving behavior is selected according to its function, it can take many forms (Skinner, 1966, 1984). Skinner (1966) described "precurrent behavior" as behavior that "furthers the reinforcement of subsequent behavior" (p. 584) and described problem solving as precurrent behavior that produces discriminative stimuli that facilitate emission of the solution.

For problem solving behavior to be evoked, the "solution" to the problem must function as a reinforcer. In the missing car key example, "car keys in hand" functions as a reinforcer because this stimulus change is required before the behavior in the larger behavioral chain of "going to work" can be emitted. Therefore, the extent to which this stimulus change functions as a reinforcer will depend upon the reinforcing effectiveness of arriving at work, or perhaps more accurately, the punishing effectiveness of arriving at work late or missing work, which can be avoided by timely departure. Motivating operations (MOs) are environmental events that alter the reinforcing or punishing effectiveness of other events and the control of behavior by stimuli associated with the response-dependent availability of those events (Edwards et al., 2019a, 2019b). MOs change the individual such that when discriminative stimuli associated with the relevant reinforcer are encountered, these stimuli evoke behavior that was previously reinforced in their presence. MOs, therefore, are another factor that must be considered when analyzing problem-solving behavior. When the required precurrent behavior does not occur, or when it occurs only briefly and then the individual “gives up,” the solution to the problem may not be adequately reinforcing at that moment.

The behavioral processes associated with chaining are relevant to many problem-solving scenarios. In Epstein’s (1981) well-known experiment, pigeons “spontaneously” solved the problem of reaching a suspended banana by emitting components of the required sequence of responses that had been trained separately: moving a box to a specific location and standing on the box. In test trials, the stimulus context consisted of a banana suspended out of reach and a box positioned too far from the banana. Although, in training, the pigeons moved the box toward a target on the wall, the problem context with no such target was sufficiently similar to the training context to evoke the behavior required to move the box to the appropriate location, beneath the banana. The box positioned beneath the banana had been encountered during training already, so it evoked mounting the box, which enabled banana pecking. Therefore, as in a behavioral chaining example, each intermediate stimulus change reinforced the behavior producing it. Unlike a standard behavioral chaining example, however, the specific problem context had never been presented, and the necessary sequence of behaviors was never previously reinforced. The pigeon’s history of conditioning resulted in generalization of successful precurrent behavior in the novel problem context. As described in Part 3 of our definition of a problem, novelty may be considered as a requirement for a context to be classified as a “problem.” The problem context may serve as a testing ground for stimulus functions that have not been directly conditioned; these stimulus functions may arise through stimulus generalization or through other processes, such as those underlying stimulus equivalence.

We can increase the chance of finding a remote control by changing our position in the environment (e.g., kneeling down, changing our orientation, or getting closer to a location) or by manipulating the environment (e.g., looking under or between cushions). We can learn to use symbols as S^{Δ} to eliminate unnecessary responses (as on a diagnostic flowchart) or as S^{D} to guide additional behavior (Skinner, 1984). We can use tick marks to indicate that an object has been inspected, use tally marks when counting, or alphabetize a list of names when searching for specific names. We can also generate discriminative stimuli by thinking; these generated stimuli may evoke additional precurrent behavior or the solution to the problem itself. Thinking is operant behavior and can be analyzed as such (Moore, 2015), but access to the relevant behavior presents some additional challenges, in particular when it is private (see Hayes, 1986; Moore, 2000; Rachlin, 2018). When solving problems, private verbal behavior (a common form of thinking) can serve as precurrent behavior that facilitates production of the solution to the problem. Reproduction or generation of rules, an example of thinking, can be particularly useful in the appropriate context. For example, while disassembling an apparatus, repetition of the rule, “righty-tighty, lefty-loosey,” may facilitate the removal of a component. When solving a puzzle, generation of rules such as, “rotating this part moves that part,” can facilitate production of the solution.

Imagining is perceptual behavior in the absence of the thing perceived ("seeing in the absence of the thing seen," Skinner, 1953), and such behavior is a common form of precurrent behavior. Imagining is necessarily covert (without appropriate instrumentation) because, unlike thinking involving verbal behavior, there is no public correlate of such behavior; it is what we do when listening, seeing, and otherwise sensing the environment, whether or not the relevant features of the environment are present or absent. With exposure to a sufficient number of exemplars, we may learn to imagine rotated objects or features of a landscape from different vantage points with great accuracy. These abilities are often shaped in practical problem-solving scenarios, such as those involved with operation of robotic equipment in medical teleoperation, underwater exploration, and mechanical work in outer space (Menchaca-Brandan et al., 2007), or those involved with playing computer games (Granic et al., 2014), but they may also be shaped by such "mundane" activities as navigating our everyday environments and manipulating commonly encountered objects.

Recall is a category of behavior that is particularly relevant to problem solving. Accurate recall entails responding in a way that corresponds with a past event when features of that event are absent in the present context. For example, we can answer questions about what we ate for dinner last night or what we did last weekend, even though the dinner contents and the weekend activities are not directly in front of us. From a behavioral perspective, questions about the past or other situations under which recall is likely to be reinforced are regarded as discriminative stimuli for such behavior (Baum, 2011; Catania, 2013; Epstein, 2014; Moore, 2015; Palmer, 1991; Skinner, 1963). These discriminative stimuli in combination with the temporally distant stimuli that correspond with the events to be recalled serve as the ultimate sources of control for recalling but, as just described, recalling is often controlled by stimuli that are generated by additional behavior, such as thinking and imagining, that is emitted in the recall process. When responding to a question, recall is typically reinforced with social consequences, but when solving a problem, successful recall is reinforced, at least sometimes, with the solution to the problem. Successfully answering a simple question often qualifies as problem solving because, in order to emit the correct response, such as "gardening" in response to "What did you do this weekend?," some additional precurrent behavior may be required (e.g., saying to yourself, "On Tuesday, I went to yoga after work, then when I got home. . ."). An example of recalling that does not qualify as problem solving is immediately responding "nine" when asked "What is three times three?" In this case, the response is under the direct stimulus control of the question.

Stimulus equivalence and related phenomena are directly relevant to problem solving. Stimuli that participate in an equivalence class, including those stimuli that share no formal similarity with other stimuli in the class, can have adaptive stimulus functions that are not directly conditioned. In a problem-solving scenario with little physical similarity to previously encountered scenarios, this additional source of stimulus control (beyond the stimulus control arising from stimulus generalization, which is dependent upon formal similarity) may significantly enhance the problem solver's chances of success. For example, when navigating to a restaurant in a large hotel, the brand (i.e., symbol) for the restaurant might appear on an elevator button. As a result of seeing the symbol beside a description of the restaurant on a sign in the lobby earlier, the symbol may evoke pressing of the correct button, leading to access to the restaurant, even though pressing buttons with that symbol has never previously gained the individual access to a restaurant. As described previously, stimulus equivalence appears to play an important role in verbal behavior. The relationship between stimulus equivalence and verbal behavior appears to be bidirectional, with one facilitating the other, but the behavioral mechanisms underlying stimulus equivalence are not completely understood. There are some promising theories on this topic (Greer & Longano, 2010; Hall & Chase, 1991; Rehfeldt & Hayes, 1998).

RFT is a theoretical account that incorporates both equivalence and nonequivalence relations such as "distinction" and other logical operations that are clearly relevant to problem solving (Hayes et al., 2001). RFT specifies that relational responding (including stimulus equivalence, one example of relational responding) is a generalized operant that results from a history of multiple exemplar training, but this explanation of relational behavior has been criticized as oversimplified (Gross & Fox, 2009). "Accurate" relational responses are often produced after a sequence of precurrent behavior. Therefore, trials in relevant experiments or circumstances in which relational responding might occur, may meet the definition of a "problem," with the relational response being the outcome of successful problem solving (Diaz et al., 2020; Miguel, 2018; Moustakis & Mellon, 2018; Palmer, 2004). Explaining problem solving with another specific type of problem solving (i.e., relational responding) may represent a valid higher-order explanation, but the extent to which this type of analysis is useful, in particular in the absence of an explanation for the problem solving that occurs in the process of relational responding, is unclear to us. Putting these issues aside, we will briefly summarize the potential contribution of RFT to our treatment of problem solving, according to our understanding of RFT as it relates to problem solving.

Hayes et al. (2001) described verbal problem solving as "pragmatic verbal analysis that changes the behavioral functions of the environment under the antecedent and consequential control of an apparent absence of effective action" (p. 96). The verbally abstracted "goal" and other stimuli that are relevant to a problem-solving situation participate in a wide variety of relational frames. For example, the verbally abstracted goal may participate directly or indirectly (e.g., via frames of coordination) in several "if–then" frames. By engaging in relevant relational behavior, the behavioral functions of a variety of stimuli may be transformed. For example, when solving the problem of getting a mobile phone signal in the wilderness, the relational networks associated with "if we gain elevation, we may get a signal," change the functions of stimuli that are related to elevation gain; the sight of a hill may serve as a reinforcer and may evoke climbing because of the relationship between frames of comparison involving elevation and frames of comparison involving signal strength. These comparative relations may result in higher hills having stronger reinforcing and evocative functions. This higher-level approach to understanding problem solving and other complex behavior is appealing because it appears to account for complex problem-solving behavior, including behavior that is otherwise difficult to explain (i.e., completely unorthodox solutions). RFT was developed, in part, to explain rule-governed behavior and to extend our understanding of verbal behavior, so these areas of inquiry are highly interrelated, as is apparent in the previous example (McLoughlin & Stewart, 2017; McLoughlin et al., 2020).

There are many other important pieces of the problem-solving puzzle, but this brief overview is sufficient for the purpose of supporting our next point. We now return to perspective taking and make the case that our efforts to understand perspective-taking behavior should be combined with our efforts to understand problem-solving behavior because these two categories of behavior have considerable overlap.

Perspective Taking as Problem Solving

An examination of the perspective-taking literature reveals that researchers have primarily investigated perspective taking using tasks that require problem solving. For example, in false belief tasks, such as the "Sally–Anne" task, the participant is exposed to a sequence of stimuli and finally prompted to respond (e.g., "Where does Sally think the marble is?"). Accurate responding depends on the participant's ability to recall where the marble was when Sally was present, in this example. Thus, some precurrent behavior is required to "solve the problem." In VPT tasks, such as the three-mountain task, the participant's selection of the picture that corresponds with a specific vantage point is reliant upon attending to features of the landscape and features in the pictures, and it may involve a series of covert responses (e.g., tacting features in the pictures that do or do not match the relevant vantage point). Likewise, with the unexpected identity task, the participant must recall or look to see what is advertised on the container when responding to questions about what others will think is in the container.

Successful completion of the tasks in the BH protocol also appears to rely upon precurrent behavior. Initial accurate performance in this task is dependent upon significant precurrent behavior in response to the key words associated with each trial type, in particular in reversed and double-reversed trials. With additional exposure to the protocol, "accurate" responses corresponding with the simple, reversed, and double-reversed conditions may come to be controlled by other stimuli, including the length of the prompt in the trial, because this is reliably correlated with the trial type (double-reversed trials have the longest prompt). With significant training, to solve the tasks, the participants need only attend to these aspects of the prompt and the arbitrary stimuli that participate in the initial grammatical frame (e.g., I have a red block, you have a blue block) and they can respond appropriately (e.g., with the longest prompt—a double-reversal—responding in accordance with the original, unchanged, statement will always be correct). In our own (unpublished) research with this protocol, participants reported using these "patterns" to respond so that they could save time answering "repetitive" and "similar" questions. In this way, the problem becomes simpler with additional exposure to the task. Even so, it appears that precurrent behavior, such as looking back at or recalling the initial statement, is still required to respond accurately.

Problem solving in perspective-taking tasks often relies upon control by stimuli that reliably predict the behavior of others. For example, in the "Sally–Anne" task, the predictive stimuli are the presence of Sally and the placement of the marble in one location; Sally looking in that same location is the behavior that reliably occurs under those stimulus conditions. Therefore, in many cases, perspective taking is solving problems involving prediction of what others will do (or are currently doing privately). "Do" should be construed broadly to include what others will think or say (or what they are thinking or imagining privately), where they might go next, how they will react to questions or other stimuli (like the sight of a spider), and so on (see Guinther, 2017, 2018). Problem solving in VPT tasks may involve control by stimuli that are predictive of others' or one's own perceptual experience if they were in a different location.

In perspective-taking tasks, "others" can include other organisms, dolls, or other inanimate objects, and hypothetical alternative positions of the self and other organisms or objects. The "solution" to perspective-taking problems (e.g., the "correct" answer in the Sally–Anne task) requires that the individual behave in accordance with the "other" having at least perceptual, but often greater, behavioral capabilities. Nevertheless, describing perspective taking as behavior that accords with others having perceptual or other behavioral capabilities does not necessitate that the perspective taker is engaging in, or capable of engaging in, verbal behavior to this effect. This description of perspective taking is reflective of the conditions under which others are likely to say someone is demonstrating perspective taking, but it says nothing of the behavioral processes that are involved in the production of such behavior. If an ape accurately predicts where a human in an ape costume will look for food, we can call this perspective taking without concluding that the ape is describing to itself, or generating an internal representation of, the perspective of the human.

In perspective-taking "problems," there are behavioral prerequisites that must be met for a participant to respond accurately. With the Sally–Anne task, these include an appropriate verbal repertoire, the ability to recall details of a story, and a history of reinforcement for predicting that people look for things where they last saw them. As with Epstein's pigeons or a mathematician solving a complex problem, the perspective-taking context evokes relevant precurrent behaviors; these behaviors in turn produce stimuli that enable the individual to solve the perspective-taking problem. Examples of skills that are common prerequisites for solving perspective-taking problems include accurate recall; tacting of facial expressions and other public correlates of private events (e.g., public correlates of "pain"); social referencing, including appropriate responding to gestures and eye gaze; and an adequate speaker and listener repertoire.

It is important to note that, as when studying problem solving, researchers administering perspective-taking tasks work under the assumption that participants have not been exposed to the specific experimental task. Otherwise, it would not be possible to draw any meaningful conclusions about a participant's ability to solve such problems (i.e., do perspective taking) in general. If a child were repeatedly exposed to the Sally–Anne task, and the response, "the box," was reinforced whereas the response, "the basket," was not, the correct response could be emitted in direct response to the final question without the participant engaging in any precurrent behavior (if "the box" was always the correct answer). Following such training, if the task were changed slightly such that the other location was correct, the participant would respond incorrectly. Therefore, for perspective-taking problems, such as those typically used to study perspective-taking behavior, emission of relevant precurrent behavior in a novel context is also a critical prerequisite for successful perspective taking. Emission of adaptive precurrent behavior in a novel context may occur as a result of stimulus generalization. But as described in our discussion of problem solving, transfer (or transformation) of the functions of stimuli that participate in equivalence (or other) stimulus classes can result in the control of precurrent behavior by stimuli in the novel context, even when those stimuli have no formal similarity to discriminative stimuli for useful precurrent behavior in previous circumstances. As a result of these processes and the interrelated processes associated with rule-governed and verbal behavior in general, a novel perspective-taking context may be a treasure trove of stimuli that evoke sequences of productive precurrent behavior, leading to solutions to the problem.

By treating perspective taking as problem solving, we must also reconsider the self-other distinction, which has been treated as a core element of perspective taking by researchers working under the prominent deictic relational frame approach within the RFT framework. The self-other distinction is not relevant in many examples of perspective taking and is just one prerequisite skill that is required to solve other perspective-taking problems. For example, in the guesser–knower task, the participant does not know the location of the object, so they do not need to discriminate between their own and others' knowledge. Instead, they must discriminate between the guesser and the knower based on the stimuli associated with their gaze (and, of course, they must discriminate between them in general when solving the task). In some perspective-taking tasks, such as the Sally–Anne task, the participant must discriminate between stimuli to which they and others have access, but this is just one of many prerequisites for success with this task. The behavioral principles that are associated with discriminating between stimuli to which the self and others have access (i.e., events that they have experienced or are experiencing) do not differ from the principles associated with discriminating between the experiences of two different "others." The stimuli associated with the self-perspective are qualitatively but not functionally different from those associated with the others-perspective (Moore, 2015). For example, Lattal (1975) and Shimp (1983) trained pigeons to report separately "what they did" and "what they said they did," effectively demonstrating self-awareness capability in pigeons, which suggests that fundamental stimulus control mechanisms can parsimoniously explain self-awareness. Nevertheless, "concept of self" or "self-awareness" is an important phenomenon with relevance to perspective taking and many other aspects of behavior.

Although we have focused on examples of experimental tasks designed to study perspective taking in this analysis, much of everyday perspective taking also appears to be accurately described as problem solving. When playing chess or go,[4] definitive examples of perspective taking, aside from well-practiced opening moves, much of the game play is filled with pauses during which the players are covertly exploring the likely outcomes of many different moves, including their opponent's likely responses. When negotiating with a partner or a potential client, thinking about what the other person wants and what they value is often an important prerequisite for presenting a satisfactory suggestion. Choosing a "good" birthday gift for a friend involves thinking about their interests and recalling earlier conversations. Precurrent behavior appears to play an important role in these and most other examples of perspective taking. However, problem scenarios that do not require much or any precurrent behavior, such as the identification of emotional states (in accordance with the standards of the verbal community) may represent examples of perspective taking that should not be classified

[4] Artificial intelligence (AI) trained using a process that is analogous to operant conditioning can now outperform even the best human players, and training that is purely operant is more successful than training based on examples from human experts. This algorithm can also produce completely novel but successful "behavior" on the part of the AI. This is further evidence that "behavior reading" can account for even extremely complex examples of perspective taking (Labash et al., 2020; Silver et al., 2017).

as problem solving. These “simple” perspective taking skills may be conceptualized as prerequisites for solving more complex perspective-taking problems.

Applying the Problem-Solving Approach

Perspective-taking deficits may be the result of broader problem-solving deficits or they may be specifically associated with inadequate control of behavior by relevant stimuli, or both. Determining where the underlying deficit lies is critical to developing an appropriate intervention. Solving perspective-taking problems is usually dependent upon control of behavior by antecedent social stimuli, including subtle facial expressions and other stimuli produced by the behavior of others, often in combination with other nonsocial elements of the environment. The functions of social stimuli, therefore, should be considered when troubleshooting perspective-taking deficits. Inadequate control by social stimuli has been implicated in perspective-taking deficits in various populations, in particular people diagnosed with ASD. For example, Gale et al. (2019) found that children who were diagnosed with ASD preferred nonsocial stimuli (videos of abstract geometric patterns) over social stimuli (videos of children’s and dogs’ faces), whereas developmental-age-matched controls showed no difference in preference between the two classes of stimuli. In addition, the outcomes that serve as reinforcers for successful perspective taking are frequently social stimuli, such as approval from others. Therefore, limited capacity for social stimuli to serve as discriminative stimuli and reinforcers represents a significant barrier to successful perspective taking. Although there are some promising approaches to assessing and addressing social stimulus deficits, we still have much to learn (Rodriguez & Gutierrez, 2017).

Success in many problem-solving tasks, including perspective-taking tasks, relies upon simultaneous control of behavior by multiple features of the environment. Stimulus overselectivity, therefore, represents a general problem-solving deficit. Stimulus overselectivity is also commonly observed in individuals diagnosed with ASD (Ploog, 2010). Verbal behavior deficits also represent a general deficit. Many general problems and perspective-taking problems are specifically verbal in nature, but problems that are not specifically verbal in nature may be solved more readily by verbally capable participants because of their ability to engage in a wide variety of precurrent behavior, including production of stimuli that participate in large networks of stimulus classes (and even asking for help). It is clear that verbal behavior deficits would place an individual at a disadvantage when solving problems, including those of the perspective-taking variety. There are certainly other general problem-solving deficits that would limit an individual’s ability to engage in perspective taking, but we will not attempt to provide an exhaustive account here. One fruitful approach to determining if a specific perspective-taking deficit stems from social stimulus issues or from more general problem-solving deficits may be to develop a task that is analogous to the perspective-taking task in question but does not involve social stimuli. If, given an appropriate training history, the individual can solve the task, this would demonstrate that the relevant precurrent behavior is available but is not being evoked (or adequately reinforced) by conventional social stimuli. In such cases, through generalization training or establishment of relevant stimulus classes, the precurrent behavior that is necessary to solve the perspective-taking problem might be brought under conventional stimulus control to address the perspective-taking deficit.

Of course, application of our technology is not limited to addressing deficits; we may also apply our understanding of perspective taking to improve early education or to enhance typically developed adults' ability to engage in complex perspective taking. These applications are also socially significant and, therefore, worthy of consideration. By treating perspective taking as problem solving with social stimuli, we are directed to consider and evaluate the functions of relevant stimuli for the individual; thus (1) consider the specific precurrent behaviors that are required to successfully complete a given perspective taking task, similar to conducting a task analysis; (2) confirm that the individual is capable of emitting the specific precurrent behaviors; (3) bring the precurrent behaviors under relevant stimulus control; (4) test for generalization to novel perspective-taking contexts; and (5) as necessary, program for generalization and/or establish stimulus classes that lead to control of requisite precurrent behavior in a variety of relevant perspective-taking contexts. This problem-solving approach to perspective taking does not invalidate promising behavioral research that has already been undertaken in this area, for example, work on establishing perspective-taking prerequisites (e.g., Gould et al., 2011; LeBlanc et al., 2003). Instead, this approach may help to clarify the specific contribution of existing research to a broader understanding of perspective taking.

Conclusion

Our goal with this analysis is not to identify every aspect of problem solving that is relevant to perspective taking but instead to call attention to the overlap between these two general classes of behavior and to highlight what appears to be a clear advantage of treating perspective taking as problem solving in many cases. Treating perspective taking as problem solving does not "solve the problem" of perspective taking. We still have much to learn about problem solving, and we propose that advances in this area would lead directly to improvements in our understanding of perspective taking. For example, as we discussed earlier, our understanding of the role of stimulus equivalence and relational framing in problem solving is still limited. But a general framework for analyzing problem solving and a good experimental foundation are already in existence. We suggest that this framework and this foundation are an appropriate starting point for a scientific understanding of perspective taking.

Data Availability Not applicable

Code Availability Not applicable

Declarations

Conflicts of Interests We have no conflicts of interest to disclose.

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Chapter 4

Experiment 3[1]

Perspective taking is Stimulus Control: Conditional Control by the Presence or Absence of "Person" Stimuli in a False-belief Task

[1] Taylor, T., Sargisson, R. J., & Edwards, T. L. (2022). Perspective taking is stimulus control: Conditional control by the presence or absence of "person" stimuli in a false-belief task. [Unpublished manuscript]. School of Psychology, University of Waikato.mi

Chapter Introduction

In any experimental analysis, it is crucial to attend to how we can differentiate the forms of stimulus control involved, which can be the physical features, structural relationships, and any other controlling properties of stimuli. Any response (or topography of responses) should indicate a certain consistency in correspondence between the presented stimulus features that control the relevant behaviour. If an experimenter misunderstands the stimulus features a participant attends to, this is detrimental to the validity of the experimental outcomes. Thus, it is essential to identify and understand the relevant functional stimuli when investigating behaviour (Urcuioli, 2013). For example, a rat is trained to press a lever in a presence of a tone of one frequency and to not press the lever in the presence of a tone with another frequency. It is possible that the rat's trainer could be unaware that the rat's response may not be elicited by the frequency of the tone, but is actually controlled by minor differences in the perceived loudness between the tones. Without examining the function of amplitude, the trainer may incorrectly assume that the frequency is controlling the response. With an experimental description of stimuli that does not consider all stimulus properties that could potentially control behaviour, the functional stimuli that may be affecting the rat's pressing behaviour are obscured. Thus, simplified models of behavioural processes are important when evaluating the complex determinants of behaviour (McIlvane, 2013). These simplified models can be, for example, an attempt to define features of physical stimuli that would be discriminated by rats, and to examine how reliably and persistently they can be discriminated even if the features of the stimuli vary somewhat (e.g., stimulus generalisation). These models can also be used to examine the possibility of the subjects being equipped with certain biological capacities, which include an inclination to respond to some species-specific stimuli and stimuli functions (i.e., the models can be used to challenge the assumption of equipotentiality[1]).

[1] In theories and mechanisms of associative learning, the equipotentiality is assumed "to apply equally to any type of stimulus and any type of response" (Domjan, 1997, p.32). However, there is empirical evidence indicating that specific features of the stimuli and responses affect experimental outcomes, despite efforts to limit the activities of participants that are irrelevant to the response of interest (e.g., sexual behaviour system of male Japanese quail, Damjan et al., 1986; discrimination of avoidance performance in rats, D'Amato & Schiff, 1964; visual object recognition performance of new-born chicks, Wood & Wood, 2016, 2021).

As discussed in previous chapters, the difficulty in finding evidence showing that participants (including infants and non-human animals) operate under the ability referred to as Theory of Mind (ToM) when engaging in perspective-taking tasks appears to be rooted in two misunderstandings. The first is failing to understand the importance of the stimulus-control aspect in discrimination learning, and the second is the reduction of the explanation to a unitary construct serving as the controlling variable. That is to say, the unitary construct (e.g., belief attribution) is difficult to measure because it could potentially involve various behavioural processes involving complex stimulus-stimulus and stimulus-behaviour relations. For example, the descriptive stimuli often regarded as the controlling variables for a subject correctly responding in a perspective-taking task (e.g., what might be commonly referred to as "being aware of," "knowing," and "seeing") may not correspond with the actual responses emitted by the subject, because these responses could in fact be influenced by other stimuli present in the task (e.g., positional cues, a set of stimuli paired by classical conditioning, etc.).

In ToM studies within the area of cognitive psychology, there has been a debate on the methodological challenges involved in identifying what component is responsible for the emission of a correct response in perspective-taking tasks. Povinelli et al. (1990) pointed out the longstanding methodological problems surrounding research on ToM, stemming from the fact that many of the commonly used ToM tasks can be explained by the presence or absence of behavioral cues. A range of diverse methodologies have been designed to find evidence favoring a ToM interpretation (Kano et al., 2022; Krupenye & Call, 2019; Lewis & Krupenye, 2021); however, ToM explanations of perspective taking should only be pursued after all possible behavioural explanations have been exhausted because behavioural explanations are more parsimonious (Heyes, 2018). Considering the extensive animal studies that have, for decades, generated positive evidence to support the principles of stimulus control, it is likely that behaviour analysis can help to resolve the debate around the methodological issues involved in understanding perspective-taking behaviour.

Taking the approach of interpreting perspective taking as a type of problem solving may advance clarification of some of the methodological and theoretical issues involved in ToM studies. As discussed by Taylor and Edwards (2021), there appears to be a lack of understanding of the stimulus-control aspect in these discussions. For instance, the emission of ToM-like responses is affected by various stimuli, both those present in the context (e.g., in experiments involving non-human animals, these include body posture, face-turning, position of arms, etc.) and those involved in a subject's reinforcement history. This stimulus-control aspect is especially important with respect to experiments involving non-human animals, because animals of most species have evolved to have specific sensitivity to conditioning with social stimuli (which in most cases directly affects the relevant reflexive behaviours). In addition, animals often have an extensive learning history with social stimuli. For example, a chimpanzee raised in a research centre most likely has been exposed to humans who may have exhibited behaviour like eye contact, pointing, and making sounds associated with reinforcement, punishment, and so on. This type of sensitivity to social stimuli is also relevant to humans. In any attempts to analyse perspective-taking behaviour, it is important to find out how the behaviour of making predictions about another person's future behaviour functions, and what the controlling variables involved in the perspective-taking scenario are.

In most experimental tasks used to study perspective taking, the underlying mechanisms cannot be determined with precision because the participants come to the experimental task with pre-experimental histories associated with many of the task-related stimuli, such as situations in which people look for items, verbal behaviour associated with anthropomorphism, and so on. This variability in understanding the underlying behavioural mechanisms can be minimised by paying attention to the various forms of stimulus control exerted by the features of stimuli in a given environment. For my third experiment reported in the manuscript below, I examined one of the well-known false-belief perspective-taking tasks, the Sally-Anne task, by creating an analogous version of it that used only arbitrary stimuli (e.g., shapes). In addition to the direct stimulus-control aspect, in solving perspective-taking tasks, people engage in precurrent behaviour that produces additional stimuli, such as thinking and imagining. As discussed in the previous chapters, many of the perspective-taking tasks involve problem-solving elements; as Palmer (1991) explains, people engaged in precurrent behaviour provide themselves with additional stimuli when a response is not under the direct control of current discriminative stimuli in the given context. The additional stimuli that are produced when a person engages in a chain of problem-solving behaviour are combined with the current discriminative stimuli in the context to occasion the appropriate response. Therefore, I focused on the effect of self-produced stimuli as well (in the experiment, participants were instructed to use two different types of such stimuli), which may serve to support the participants' discrimination learning. Demonstration of participants' accurate performance in these tasks would provide evidence to support the hypothesis that an emission of the correct response in the traditional Sally-Anne task can be explained by stimulus-control mechanisms.

Perspective taking is Stimulus Control: Conditional Control by the Presence or Absence of "Person" Stimuli in a False-belief Task

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Abstract

Theory of Mind (ToM) has remained a prominent theory for explaining perspective taking as the ability of mental attribution. However, there has been methodological difficulty in finding evidence showing that participants operate under the ability referred to as ToM when engaging in perspective-taking tasks. The difficulty appears to be rooted in misunderstanding of the importance of the stimulus-control aspect in discrimination learning, and the reduction of the explanation to a unitary construct serving as the controlling variable. In the current experiment, we adopted a strictly behavioural approach to explaining successful performance of participants on a non-verbal task analogous to the Sally-Anne task. The components of this task were stimuli and stimulus changes presented through the conditional-discrimination procedure that we hypothesized is responsible for accurate performance on the Sally-Anne task. The participants were given a series of training trials containing arbitrary stimuli, exposing them to stimulus changes and feedback corresponding with the concept that someone will look for something in the place that they have last seen it. This training was interspersed with tests that were analogous to the Sally-Anne task. Demonstration of accurate performance in these tests would provide evidence in support of our hypothesis that accurate performance in a common false-belief task can be explained with stimulus-control mechanisms. In Experiment 1, 61% of participants (50% in Experiment 2, prior to intervention) successfully discriminated the pattern of stimulus changes. In Experiment 2, the effectiveness of additional naming and story-making interventions were evaluated by prompting participants to use their verbal repertoires for self-generating supplemental stimuli to increase the accuracy of their responding. After the additional naming and story-making intervention, 88% of participants successfully discriminated the stimulus pattern. The current study demonstrated that responding correctly to the traditional Sally-Anne task can be explained by a behavioural process known as conditional discrimination.

Keywords: theory of mind, Sally-Anne task, false-belief attribution, conditional discrimination, stimulus control

Perspective-Taking Tasks are Just Stimulus Control: Responding under Conditional Discrimination of Presence or Absence of "Person" Stimuli in False-belief Task

Experiments investigating the perspective-taking ability of non-verbal subjects, including non-humans (animals), infants, and people with learning disabilities, are often based on a false-belief task (Baron-Cohen et al., 1985; Wimmer & Perner,1983). False-belief tasks examine whether participants can impute mental states to others, an ability called "Theory of Mind" (ToM) (Premack & Woodruff, 1978). In one common task, known as the Sally-Anne Task (Baron-Cohen et al., 1985), participants are asked to indicate where one of two dolls involved in the scenario will look for an object, which is indicative of the doll's "belief" about the object's location. The object is moved from an initial location (e.g., from inside a basket) to another place (e.g., inside a box), and this process is "seen" by one of the dolls but not the other. For non-verbal subjects, the anecdote is generally presented with visual cues (and occasionally non-verbal sounds) to signify the start of the probe trial, such as a short movie, a puppet show, or an enactment by human actors. The dependent measure is the accuracy of the subject's pointing, or which location they otherwise indicate (e.g., verbally).

Researchers and practitioners refer to accurate performances on perspective-taking tasks as evidence of a person or animal having "ToM" ability, which is often referred to as the central element of perspective taking. ToM is often framed as an "all-or-none" construct (the participant either has it or does not), particularly in nonhuman animal studies where the successful outcome is typically determined by whether the subjects' correct responses exceed chance performance (e.g., with chance performance at 50%, even 70% correct responses was interpreted as the subjects "having" ToM ability; Krupenye et al., 2016, 2017). In addition, the outcome of ToM studies appears to depend heavily upon task characteristics, because slight modifications to the procedural details lead to different outcomes. For example, because the classic "three-mountains task" (Piaget & Inhelder, 1967) was difficult for preschool children to solve, in follow-up studies, other researchers modified the task to be more child-friendly, for example by using familiar objects (e.g., Sesame Street characters) and a diorama with a lake and houses (Borke, 1975; Donaldson, 1979; Flavell.,1986; Fishbein et al., 1972; Hughes, 1975). The studies demonstrated that preschool children were successful at distinguishing what would be visible or invisible from various positions in relation to the target and, therefore, solving the equivalent of the “three-mountains task.”

ToM is just a construct, not a cause of behaviour; this conceptualisation is of little value if our aim is to predict and control behaviour. If the task features are critical determinants of success in ToM tasks, then we should examine how these task features (i.e., stimuli) come to influence participants' behaviour. By looking at perspective taking through the lens of “stimulus control,” we can more objectively examine this interesting class of behaviour. In the example of a false-belief task, if one can learn to discriminate the change of the stimulus (which could be the change in location of a toy, e.g., from left to right, from a basket to a box, etc.) depending on the presence of either conditional stimulus (e.g., the Sally or Anne doll), then one can explain performance in the task without reliance upon the nebulous concept of ToM. The false-belief task can be operationally defined as a subject’s ability to discriminate stimulus changes in the environment (the stimuli could involve people, self, others, etc.). For further discussion of this point, see Taylor and Edwards (2021). In addition to direct stimulus control, participants engaged in perspective-taking tasks can also be engaged in private behaviour (e.g., thinking and imagining), which can produce additional stimuli. For example, a person can talk to themselves to provide a description of an event not being dictated verbally, such as “Sally has not seen Anne change the location of Sally’s marble, therefore Sally must still think that her marble is at the original location.”

A task analysis is essential when evaluating perspective taking through the lens of stimulus control because researchers must identify which stimuli and stimulus changes may be responsible for the relevant behaviour. In a complex task environment, it is always difficult to determine with certainty the specific features of the environment that are responsible for success in the task (McIlvane, 2013). The complex task environment may also evoke irrelevant behaviour. This includes the instructional complexity involved in many of the common perspective-taking tasks. For example, in the Sally-Anne task, even just one stimulus (e.g., the Sally doll) consists of multiple dimensions (e.g., shape, colour, movement, such as presence and absence, and verbal stimuli, such as the name “Sally”). A ToM task with verbal instruction generally comprises a variety of anthropomorphic descriptions of the setting or “intentions” of the Sally doll (e.g., “she wants” to play with her marble, "she owns" the basket, etc.). This lack of control over the stimulus presentation may not only interfere with the subject's discrimination learning, but it also creates ambiguity in determining which stimuli control task-related responses. Moreover, we do not have a clear understanding of how the functions of the specific task stimuli may influence a participant's correct response in the perspective-taking situation (e.g., a social construct of ownership conveyed with words such as "my basket" and "Sally's toy," which implies that the toy "belongs" to Sally and not to Anne). The Sally-Anne task can be represented with arbitrary stimuli and stimulus changes, which can help to clarify the degree to which fundamental stimulus-control mechanisms can explain accurate performance in such a task. Additionally, if participants can demonstrate accurate performance in an arbitrary version of the Sally-Anne task, an analysis of the type of training that is required to produce such performance will help to clarify the history that is required for the generation of relevant stimulus control.

In the following experiment, we adopted a strictly behavioural approach to explaining successful performance of participants on a non-verbal task analogous to the Sally-Anne task. The components of this task were stimuli and stimulus changes that we hypothesised are responsible for accurate performance in the Sally-Anne task. To control historical stimulus functions, the experimental task included no social stimuli; all stimuli were arbitrary shapes. The participants were given a series of training trials, exposing them to stimulus changes and feedback corresponding with the concept that someone will look for something in the place that they have last seen it. This training was interspersed with tests that were analogous to the Sally-Anne task. Demonstration of accurate performance in these tests would provide evidence in support of our hypothesis that accurate performance in a common false-belief task can be explained with stimulus-control mechanisms.

Experiment 1

The main purpose of Experiment 1 was to investigate whether participants could solve the analogous version of the original Sally-Anne task. In this task, all of the social stimuli were substituted for non-social stimuli (e.g., geographic shapes), and no verbal instructions were provided, except for the instructions to "press M" or "press Z" at the end of the trial sequence. We hypothesised that participants would be capable of accurate performance in this task following a period of training with relevant components. Such an outcome would be supportive of a behavioural explanation of the processes underlying successful performance in the traditional Sally-Anne task.

To pass the analogous Sally-Anne task, participants needed to reliably select one of the stimuli that appeared in the bottom area of the monitor the last time it moved (a “grow and shrink” movement) in the presence of the sample stimulus that was presented at the top of the monitor during the choice phase of a trial. This was analogous to a participant in the Sally-Anne task selecting the location to which an object was moved the last time a character in the vignette was present. Successful performance was evidenced by an increase in the percentage of correct responses across each of the three separate test blocks (i.e., above 75% correct). The test trials provided in the analogous Sally-Anne task were arranged in three blocks, one at the outset of the experiment to test the participants' performance prior to relevant training, one after a block of training trials designed to teach them the underlying component skills, and one after a second block of training trials which were designed to enhance their repertoire relevant to this analogous task.

Method

Participants

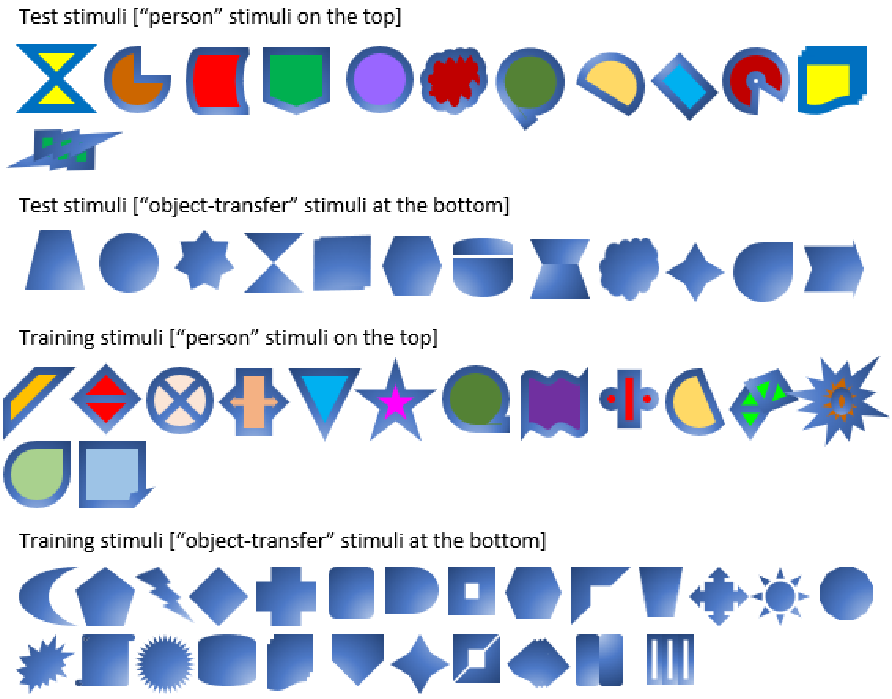
Eighteen university students were recruited through flyers and online advertisements through the School of Psychology. All were given the choice either to receive course credits (1% per hour of participation) or the chance to win a $20 shopping voucher in a random draw. The experiment was approved by the Division of Arts, Law, Psychology & Social Sciences Human Research Ethics Committee of the University of Waikato [FS2020-62].

Setting, Apparatus, and Materials

The experiment was conducted online. Participants were required to have access to either Chrome or Firefox internet browsers for the experimental programme to run properly. They interacted with the online task through their own computer mouse and keyboard. Visual Studio 2017 (https://visualstudio.microsoft.com) and Three.js library (https://threejs.org) were used to present the experimental stimuli, and the Google Drive API was used to record data. Participants were asked to complete an online computer task that sequentially presented both tests and training blocks in the order indicated in Table 1. Stimuli presented in the computer task were all arbitrary shapes (Figure 1).

Figure 1

Arbitrary Stimuli Used During Test and Training Trials



Note. All stimuli were 5cm wide and 5cm high on the monitor.

Procedure

The participants received an email that included a link to the experimental task. After they consented to participate, the following instruction was presented on the computer monitor for them to read:

> Welcome to the experiment!
>
> You are about to begin a series of computer tasks where you will be shown different shapes; you will make responses by pressing specific keys on your keyboard.
>
> - The programme consists of multiple levels of training and testing trials. You need to pass each level to go to the next one. You will be learning how to answer correctly through trial and error.

- Some blocks of trials provide you with no feedback and, while you may feel like you are doing repetitive tasks, this is expected. You just need to try to answer correctly in each trial.
- The experiment will take approximately 1 hour.
- You can take a break, if necessary, during the experiment.
- Please ask the experimenter if you have any questions.

The participants, then, clicked the "next" button to read the following first instruction.

> After each short presentation of symbols and movement, you need to select either Z or M key on your keyboard. You will receive no feedback during the following trials.

Then, the participants clicked on the "start" button at the bottom of the screen to proceed to take the Test 1 block of trials.

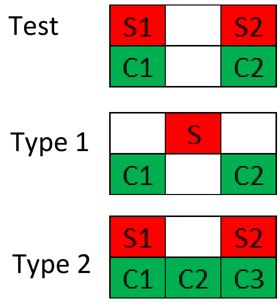
Test blocks

The three test blocks (Tests 1, 2, and 3, see Table 1) were all identical, except for the stimuli presented. Each test block involved 16 test trials.[1] In each test trial, two inanimate stimuli appeared at the top area of the screen, and another set of two stimuli depicting a movement (i.e., a "shrink and grow" motion) appeared at the bottom of the screen (Figure 2; see the video footage). In the experiment, a participant undertook a total of three test blocks. Test 1 was provided at the start of the experiment, to measure the level of accuracy in the pre-training responses as a baseline.

[1] The number of trials for each test and training block was decided for the purpose of controlling all possible extraneous stimuli involved (i.e., stimulus dimensions such as positions related to stimulus movement and the location of answer stimuli either left or right).

Table 1

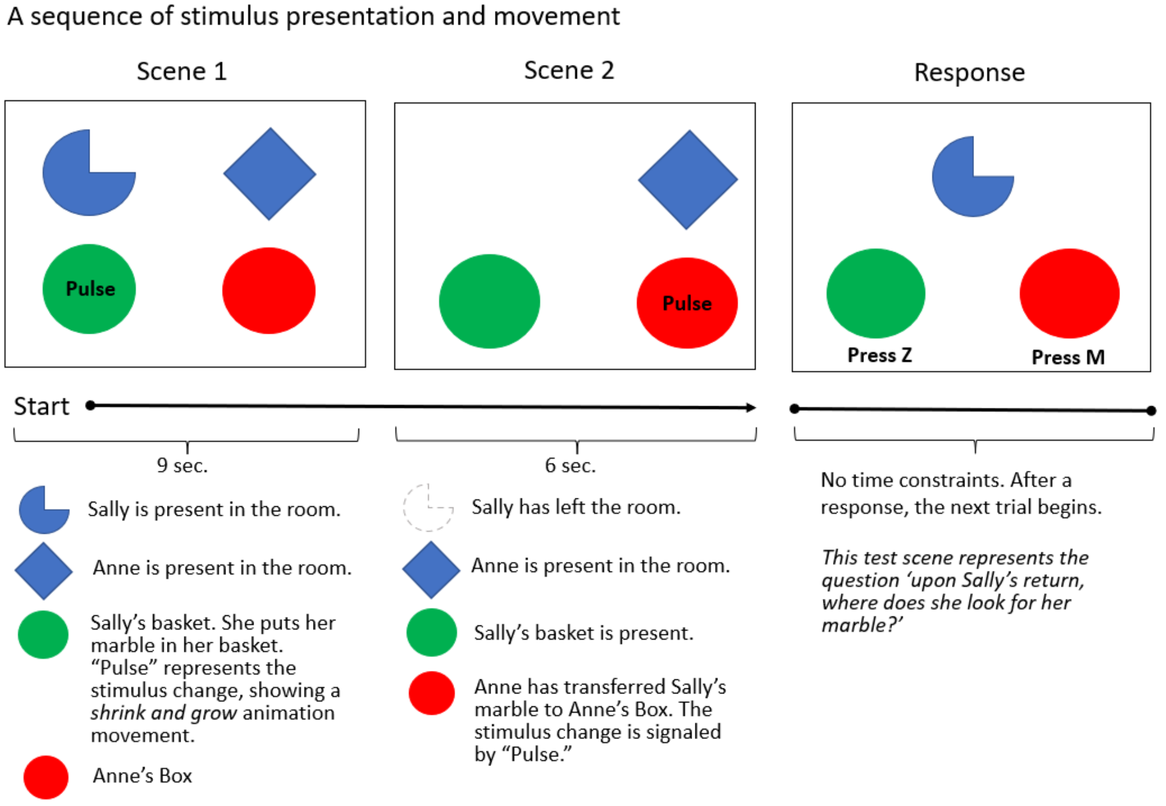
Test and Training Blocks that Appeared During the Online Experiment

Order	Types of Stimulus Configuration	Test or Training blocks	Stimulus Configuration Diagram
1	Test	Test 1	
2	Type 1	Training A	
3	Type 1	Training B	
4	Type 1	General Training I	
5	Type 1	General Training II	
6	Type 1	General Training III	
7	Test	Test 2	
8	Type 2	Training C	
9	Type 2	Training D	
10	Type 2	Training E	
11	Test	Test 3	
12		Post-experimental question	

Note. The diagrams in the column labelled *Stimulus configuration diagram* indicate the layout of stimulus presentations on the computer screen. Type 1 and 2 represent the blocks of training series provided before or after Test 2. S, S1, and S2 represent sample 'person' stimuli. C1, C2, and C3 are 'location' stimuli resembling a basket and a box in a false-belief task, which sometimes showed an animated movement resembling a change in stimulus functions (e.g., object transferring) (see Figure 2).

Figure 2

A Diagram Representing the Adapted Sally-Anne False-Belief Task (Baron-Cohen et al., 1985) with Inanimate Stimuli



Note. This diagram represents one example of a test trial with sequential presentations of stimuli and the "shrink and grow" (i.e., pulse) movement of bottom stimuli. Scenes 1 and 2 were followed by a response scene, in which a participant selected either bottom stimulus by pressing the Z or M key.

Training blocks

Training trials were divided into two types, based on the stimulus arrangement (see Table 1). A series of Type 1 training blocks were provided before Test 2, and blocks of Type 2 training blocks were provided after Test 2 (a list of all training trial details is available in Appendix A and B). Even though the training blocks were categorised into two different types, both types of training block were designed to bring the participants' responses under the control of the combination of the stimulus that was present at the top of the final response scene and the bottom stimulus that most recently moved when the top stimulus was present during the previous scenes. After selecting the appropriate stimulus, the participant received feedback of either the words "correct" or "wrong" appearing in the centre of the screen. The conditional discrimination with control by a historically present stimulus presented in the animated scenes resembles a stimulus discrimination of a "false-belief" associated with a protagonist (e.g., Sally) during the Sally-Anne test. The purpose of the training trials was similar to teaching the participants that "people" look for things in the last place they "saw" them.

To establish these fundamental stimulus functions, Type 1 training blocks were arranged using stimulus configurations with reduced numbers of stimuli compared to the test trials (Figure 2, Table 1). Appendix B provides an example from each training block (A, B, and General Training I, II, & III) with an explanation of the detailed stimulus-presentation sequence. Appendix B also presents a simplified version of Figure 2, with stimuli presented as coded symbols.

Training Block A contained four trials. Participants progressed to the next training block if they made no more than one incorrect response. If the participants made two or more incorrect responses, they repeated the training block from the beginning until they reached the mastery criterion. A block in Training B contained four trials and used the same passing criterion as Training A (i.e., no more than one error response in order to proceed to the next General Training block).

Each of the three General Training blocks contained a mix of five different types of exemplars (Appendix B; PA, AP, APP, PAP, and PPA types). "P" is an abbreviation for "Present," referring to a condition where one of the bottom stimuli was showing the "grow & shrink" movement while an S stimulus (Table 1, a sample stimulus) appeared simultaneously in a designated position at the top area of the stimuli allotment. The "P" condition is analogous to the "true-belief" depicted in the traditional Sally-Anne task, where the toy marble was placed in a box while Sally was present. "A" stands for "Absent," and indicates a condition where one of the stimuli at the bottom is showing the movement while the S stimulus at the top is absent. "A" is therefore analogous to the transfer of the toy from the basket to the box in Sally's absence. In the final response scene, selecting the bottom stimulus that was moving under the condition "P" was always reinforced. This indicates the "false-belief" discrimination from Sally's perspective (i.e., Sally still believes her toy be in the box because the toy was moved in her absence). The stimulus discrimination learnt from Training Blocks A and B was a prerequisite for the General Training block because these trials were presented under the "P" condition only, without involving any of the trials under the "A" condition. The purpose of the mixed General Training block was to strengthen the participants' correct responses under the "P" conditions by going through the multiple exemplars in combination with the "A" stimulus condition.

Participants were allowed to repeat each general training block a maximum of three times. Each one of the training blocks involved 16 trials of mixed trial types, and 90% correct responses were required to proceed to Test 2 (i.e., one error was allowed). If the participants repeated the Training Block I three times and did not reach the passing criterion, they proceeded to Training Block II anyway. This block had the same numbers of training and sequences as Training Block I, except all the trials were presented with a new set of stimuli. Once the participants met the criterion, they proceeded to Test 2. If they failed, they took Training Block III with the same passing criterion. If the participants did not reach the criterion for Block III, they still proceeded to Test 2, for the purpose of investigating whether there would still be an improvement in Test 3 performance as the result of completing the second block of Type 2 training trials.

After Test 2, participants proceeded to Type 2 training blocks (see Table 1, Type 2 configuration). The presentation of the stimulus sequence in the training trials was very similar to how each of the trials under Tests 1, 2, and 3 were arranged, except that there were three bottom stimuli present. All three different Type 2 training blocks (C, D, and E) contained longer sequences of stimulus and motion presentation than participants were exposed to in the previous Type 1 training blocks. The complex Type 2 training blocks consisted of a combined stimulus sequence that appeared in the previous Type 1 training, and a stimulus configuration that included two top stimuli and three bottom stimuli that could “grow and shrink.” Examples from each training block (C, D, and F) are provided with an explanation of the detailed stimulus presentation sequence in Appendix B.

In Training Block C, there was a total of 14 training trials. Participants repeated the block until reaching the criterion of 85% correct responses (allowing for up to two error responses).

In Training Block D, a total of eight training trials was provided. The criterion to pass this block was 85% correct responses; one error was allowed. If a participant did not meet the criterion, the participant repeated the block of training trials up to three times. If the participant did not reach the criterion even after repeating the block three times, they still moved onto the next training block.

In Training Block E, a total of 12 trials per training block was provided. The criterion to pass this block was 85% correct responses; two error responses were allowed. If a participant did not meet the criterion, the participant repeated the block of training trials up to three times. If a participant did not reach the criterion even after repeating three times, they still moved on to Test 3.

Post-experimental question

After completing Test 3, participants were shown the following question on the monitor and provided with a textbox to type in their answer:

> "Did you figure out why the correct answers were correct? If so, please explain why they were correct. If not, what kind of pattern did you identify and follow?"

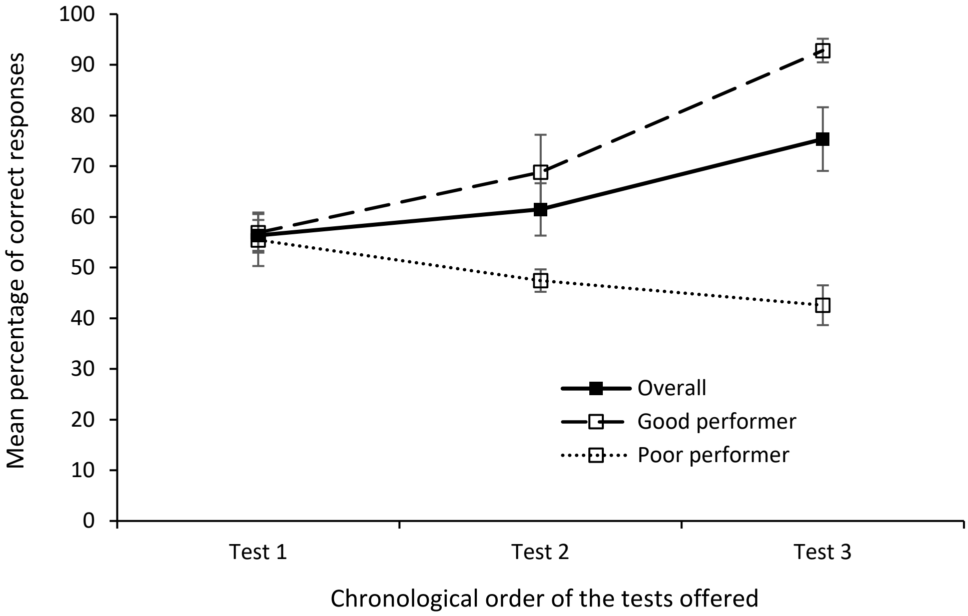
Once they completed the online task, the monitor directed participants to a page to fill in an application to receive course credit.

Results

The mean percentages of correct responses of all 18 participants for each test are presented in Figure 5. A one-way repeated-measures ANOVA in SPSS was conducted to compare the scores obtained from Tests 1, 2, and 3. The statistical software SPSS (https://www.ibm.com/analytics/spss-statistics-software) was used for all analysis discussed in this paper. Since Mauchly's test has been criticised for failing to estimate sphericity correctly (Field, 2018), we used the Greenhouse-Geisser correction ($\mathcal{E}$ = 0.96). There was a significant difference in the scores across the three tests, $F(1.91, 32.6) = 4.42$, $p = .02$ $\eta_p^2 = .21$. The pairwise comparisons for the main effect were corrected using Bonferroni adjustments. Even though there was a significant improvement in scores from Tests 1 and 3 ($p = .03$), there was no significant difference between the scores of Tests 1 and 2, or between Tests 2 and 3.

Figure 5

Mean Percentage of Correct Responses for the Three Tests



Note. The solid line indicates the overall result of the total of 18 participants in Experiment 1, and the dashed lines indicate the difference between the good and poor performances (*n* = 11 and 7 each) among the 18 participants. The error bars represent the standard error of the mean of the percentage of correct responses.

In addition, we conducted another one-way repeated-measure ANOVA to test if there were any significant differences in the number of error responses between the five different units of stimulus presentations (i.e., PA, AP, APP, APA, and PPA types) during the blocks of general training. The difference among the training types was non-significant, $F(1.8, 30.4) = 2.57$, $p = .098$, $\eta_p^2 = .13$. Thus, one trial type did not seem to contribute to the improvement in the test scores more than any others.

We therefore examined the data of the 11 participants (see Table 2; Participants 1, 2, 4, 5, 6, 8, 11, 13, 16, 17, and 18) whose test scores increased from Test 1 to 3, and who also demonstrated faster acquisition of the criterion for both Type 1 and 2 training sessions (e.g., the training duration was recorded at an average of about of 36 min, compared to the mean duration record for all participants of about 49 min). We conducted a one-way repeated-measures ANOVA separately for the 11 participants' scores obtained from each test. Using Greenhouse-Geisser correction based on estimates of sphericity ($\mathcal{E} = 0.78$), the difference among the mean scores of tests was significant,

$F(1.57, 15.57) = 14.66$, $p < .001$, $\eta_p^2 = .59$. Tests of within-subjects planned contrasts indicated that the test scores significantly improved between Test 2 and 3 ($p = .006$). However, there was no significant improvement in the test scores between Test 1 and Test 2 ($p = .17$). This indicates that participants who did well in terms of their overall test scores improved after the second set of training trials. Of the total of 18 participants, seven did poorly on the tests overall (Table 2; Participants 3, 7, 9, 10, 12, 14, and 15) and took approximately 71 min, on average, to complete both the Type 1 and 2 training sessions. Their test scores were lower or unchanged from Test 1 to 3 (e.g., the average score of Test 1 was $M = 55.4$; Test 2, $M = 47.4$; Test 3, $M = 42.5$).

Table 2

Summary of Participants' Overall Performance on Online Experiment 1

Participants	Test 1 (%)	T-A	T-B	GT-I	GT-II	GT-III	Test 2 (%)	T-C	T-D	T-E	Test 3 (%)
1	81	1	1	1	1	-	100	1	1	1	94
2	63	1	2	1	1	-	44	1	2	1	94
3	81	1	2	NP	NP	NP	56	5	NP	NP	63
4	44	1	1	1	1	1	100	1	1	1	94
5	56	1	2	3	2	2	94	1	1	1	100
6	56	1	3	1	1	-	56	1	NP	NP	75
7	63	1	1	2	2	1	38	1	NP	1	50
8	56	1	1	1	-	-	56	1	1	1	100
9	50	5	1	2	1	1	50	1	NP	NP	38
10	50	1	1	2	1	1	50	2	NP	NP	33
11	50	1	1	3	2	2	50	2	NP	NP	100
12	50	2	1	NP	NP	NP	50	9	NP	NP	38
13	75	1	1	1	1	1	56	1	1	NP	88
14	56	1	7	NP	NP	NP	44	1	3	NP	38
15	38	1	1	2	2	2	44	1	1	NP	38
16	38	1	1	1	1	-	38	2	3	NP	88
17	63	1	1	1	1	1	63	1	1	1	88
18	44	2	2	1	1	1	100	1	1	1	100
Mean (%)	56.33						60.5				73.28

Note. This table shows the percentage of correct responses on each of the three tests, and the number of repeated blocks of training trials completed until the criteria were met for each participant. On the top column heading, the T-A ["T" is abbreviated for Training], T-B, GT-1 ["GT" is abbreviated for General Training], GT-II and GT-III, T-C, T-D, T-E columns represent the chronological order as the experiment progressed (i.e., increasing from the simple to complex sequential patterns and cell arrangements from left to right of the table column). NP means "not passing," indicating that the participant did not meet the criteria and carried on to the next training or test trial. A dash [-] indicates that the participant skipped the training trials because they had already passed General Training I or II.

The post-experiment text responses of the participants are summarized in Table 3. The textual responses in bold type indicate responses provided by participants who did well in the experiment (i.e., good performers, see Figure 5). These responses match with the contingency tested through the reduced Sally-Anne task (i.e., selecting the stimulus appearing in the bottom area of the monitor that moved when the top stimulus was most recently present). However, the participants who did poorly on the experiment appeared to have difficulty describing a generalised pattern of the stimuli and their movement; rather they appeared to focus more on the specific dimensions of the stimuli (e.g., colour, position, sequence of stimulus presentation, frequency of stimuli appearance, etc.).

Table 3

Textual Responses Made by Participants to the Post-experimental Text Questions about How They Achieved Correct Answers

Participants	Textual responses
1	***"The correct answers were the stimuli on the bottom line that flashed when the top line stimuli were present."***
2	***"The last icon to move on the bottom row for the corresponding top icon."***
3	*"No, I did not. I tried to follow a pattern but couldn't."*
4	***"Yes, whatever stimulus was last shown with the coloured symbol was the correct one."***
5	***"Yes, I think so. The correct plain shape was the last one to flash while colour one was present. For example, if the sun-like symbol was the last one to flash before the yellow shape on top disappeared, this was correct, even if other plain shapes flashed after."***
6	***"If the picture in the top disappeared, and the picture down the bottom flashed, it wouldn't be correct, as the one prior would (that flashed before it disappeared.)"***
7	*"Not really. I figured if an object did not appear on the screen, the item below it was not the correct answer."*
8	***"A top colour/shape had to be present. When there was no top colour/shape, the blinking bottom row was irrelevant. So I made my selection based on what bottom shape blinked last when a top colour/shape was present."***
9	*"The pattern I followed was, what object was present before the coloured object at the top disappeared unless they both disappeared then reappeared then it was the object straight after both colours appeared."*
10	*"Yes, for some of the patterns. I think that with the purple star exercise I needed to select the shape that 'popped out' immediately before the purple star disappeared."*
11	***"I think that the pattern was for whichever shape was shown on the top row at the end to select the shape on the bottom row that had made movement last before the top one had disappeared."***
12	*"Sort of, I found some sort of repeating pattern types using the flashing icons and mostly ignoring the centre icon. I may be wrong though. It was a very difficult experiment that I struggled almost the entire way through and kept feeling like I was going somewhere just to find out only some patterns."*

Participants	Textual responses
13	***"I didn't figure out all the patterns, and found that frustrating by the end, but I did figure out that generally the answer was the shape that flashed before or after the top shaped faded in or out."***
14	*"I didn't figure out why the answers were correct. I tried pressing the shape that flashed after another shape disappeared but ultimately, I didn't figure it out."*
15	*"The only one I recall involved choosing which shapes came following/before certain presentations of other shapes. I cycled through various patterns (that both worked and didn't, I also can't recall all of the patterns I tried); I tried counting the number of times an object was squeezed and how that worked in relation to whether the other shapes faded or not, I tried visualizing a circular sort of image for one set, I tried doing positionally based patterns (e.g., if the one above had been the last presented, maybe the one below it was the option), I tried placing in time whether the object faded before or after a certain action of another shape, I tried the first and last shapes pressed after other shapes were presented. One set I noticed followed a predictable pattern, but I was unable to figure out which shape corresponded with the other shapes in spite of this."*
16	***"I identified that often it was the last object before the top one faded."***
17	***"I thought the bottom-line object which could erase the top line object is the answer."***
18	***"I realised the shape that flashed last in regard to the coloured shape shown above was correct."***

Discussion

There was a significant increase in response accuracy, seen in the improvement in the average scores obtained from the performance of all 18 participants, from Test 1 to Test 3 in Experiment 1. This indicates that some of the participants' responses were under the control of the conditional discriminative stimuli of the basic stimulus pattern presented in the analogous Sally-Anne false-belief task. As correct responding can be entirely explained by stimulus control in our study, perspective-taking in the false-belief task generally may be explained in similar terms. As indicated in the post-hoc statistical analysis of the 61% of the participants (11 out of 18 total) who did well in Test 3, these participants significantly improved their performance from Test 2 to 3, compared to the baseline performance from Test 1 to Test 2. This suggests that either the number of training trials (i.e., Type 1 and 2 training combined) or the Type 2 stimulus configuration (two stimuli on top, S1 and S2; three stimuli at bottom, C1, C2, and C3) may have helped to improve their discrimination learning. However, the basic stimulus pattern (i.e., selecting the stimuli appearing in the bottom area when it has moved the last time that one of the top stimuli was simultaneously present) was consistently presented throughout the training phases; the only elements that changed were the length of each trial and the Type 1 and 2 stimulus configurations provided in the first (before Test 2) or the second phase of training (after Test 2). Overall, these exemplars provided in the block of training trials helped to strengthen the participants' discrimination learning, which was supported by the answers to the post-experimental questions, in which the participants who increased their scores gave answers that indicated they had identified and described the core stimulus pattern.

On the other hand, 38.8% (seven of 18 participants) failed to show discrimination of the core stimulus pattern. Considering how easy it is for verbally competent adults to pass the traditional Sally-Anne task, it is not immediately clear why there was a substantial number of failures in the current experiment, or in other words, why the reduced Sally-Anne task was so difficult for some of our participants. In a pilot study we conducted separately to test the Sally-Anne task, 41.6% of the participants (five of 12) also failed. Thus, we had observed some consistency in the numbers of failures in the reduced Sally-Anne task. We decided to explore this issue in Experiment 2.

Experiment 2

Experiment 2 was conducted to investigate why some participants did not improve their scores over the three tests in Experiment 1. Due to the Covid-19 pandemic, we provided the previous experiments online (a pilot study and Experiment 1), thus there was no direct supervision to control extraneous variables, which may have affected participants' performance. It could be that the amount of training was insufficient for the participants who performed poorly. However, we observed a decrease in the test scores of 57% (four of 7) of the participants across the three tests in Experiment 1, even though they had met the training criteria for the mixed training trials with the Type 1 stimulus configuration. We hypothesised that a different type of training may have better assisted their discrimination learning.

Moustakis and Mellon (2018) demonstrated that self-generated stimuli involving naming and story-making improved participants' accuracy in deriving the relational property of transitivity in a stimulus-equivalence task. According to the authors, the "emergence" of transitivity relations in the equivalence test constitutes problem-solving (a similar notion was suggested by Holth [2008]); the authors explained that when one is in a situation in which a response is not under direct control of current discriminative stimuli, the situation requires "the precurrent constitution of discriminative stimuli, where the probability of 'solving' the problem is jointly controlled by events in the current field, as well those constructed by the problem solver" (p. 451). Understanding the role of self-produced stimuli and the conditions under which people are under the contingency of the reinforcement is important for successful problem solving. Moustakis and Mellon's interpretation is applicable to the current experiment, especially for understanding what an individual is doing when no effective responding is evident in the analogous version of Sally-Anne task. Self-generated stimuli, produced through practices such as naming of an object and story-making interventions, may serve as supplemental discriminative stimuli that specify the relevant stimuli or stimulus relations, especially in a context with a paucity of discriminative stimuli. The act of producing the supplemental stimuli may increase the chances of reinforcement, and perhaps the future occurrence of the act of self-producing stimuli may increase when the person is later in a novel context.

In Experiment 2, we examined whether we could facilitate participants' stimulus-discrimination learning of the core stimulus pattern. On Day 1, we conducted the same test as in Experiment 1, except in a room with an experimenter present. We invited those who did not improve their test scores on Day 1 to participate in a second session, in which the interventions of naming and story making, adapted from Moustakis and Mellon's (2018) study, were provided for the purpose of increasing stimulus control to see if this led to any improvement in their test scores on Day 2.

Method

Participants

Sixteen university students were recruited through the same methods as in Experiment 1. All were given the choice to either receive course credits (1% per hour of participation) or the chance to win a $20 shopping voucher in a random draw. On Day 1 of the experiment, the scores of a half of the participants did not improve across the three tests. We invited these eight participants to come back for the Day 2 experiment, and seven of them returned.

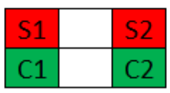
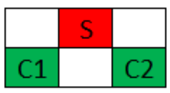
Procedure

The experiment was carried out at the university campus, in a room with a computer. The first author was present for the duration of the experiment to monitor each participant's progress and to answer enquiries. Once a participant was seated, the same instructions as in Experiment 1 were presented to them to read. This time they were presented on a piece of paper, instead of on a computer. Then, the participants began working on the same computer task used in Experiment 1 (see Table 1). Upon completion of the task, participants whose scores did not increase from Test 1 to Test 3 (i.e., the scores were unchanged or lower than the Test 1 scores) were asked whether they would like to come back for the follow-up experiment (i.e., the Day 2 experiment). The participants could obtain additional course credit or have a second entry into the draw to win a $20 shopping voucher if they did not want course credit. Participants who agreed to come back made their appointment for the next session before leaving. All appointments were scheduled for a time within 7 days of completing the Day 1 experiment.

The Day 2 experiment was conducted in the same room as the Day 1 experiment, and the first author was present. However, the computer task in the Day 2 experiment was modified to accommodate the naming intervention, which was followed by the story-making intervention (Table 4). The content of the test and training trials, such as the stimulus sequences, trial numbers, and length, remained the same as in Experiment 1. However, we removed the blocks of Type 1 Training A & B, and the Type 2 Training C, D, and E to shorten the overall length of the computer task. The stimulus sets were replaced with novel sets.

Table 4

Test and Training Blocks that Appeared During Day 2 in Experiment 2

<table>
<tr><th>Order</th><th>Types of Stimulus Configuration</th><th>Test or Training blocks</th><th colspan="2">Stimulus Configuration Diagram</th></tr>
<tr><td>1</td><td>Test</td><td>Test 1</td><td rowspan="5">Test</td><td rowspan="5">
</td></tr>
<tr><td>2</td><td>-</td><td>Naming Instruction</td></tr>
<tr><td>3</td><td>Type 1</td><td>General Training I</td></tr>
<tr><td>4</td><td>Test</td><td>Test 2</td></tr>
<tr><td>5</td><td>-</td><td>Story-making Instruction</td></tr>
<tr><td>6</td><td>Type 1</td><td>General Training II</td><td rowspan="5">Type 1</td><td rowspan="5">
</td></tr>
<tr><td>7</td><td>Type 1</td><td>General Training III</td></tr>
<tr><td>8</td><td>Type 1</td><td>General Training IV</td></tr>
<tr><td>9</td><td>Test</td><td>Test 3</td></tr>
<tr><td>10</td><td>-</td><td>Post-experimental question</td></tr>
</table>

Once a participant was seated, on the computer monitor they saw the same instructions as in Experiment 1, asking them to press either the Z or M key on their keyboard after a short presentation of symbols and movement. After reading the instructions, participants pressed a button located at the bottom area of the screen to proceed to the first block of Test 1. During the test trials, no feedback was provided for any responses. After completing Test 1, the following 'naming' instruction was presented on the monitor:

> You are going to see different symbols; these symbols will sometimes move (grow and shrink). There is a good chance you have not seen the symbols; nevertheless, each symbol will remind you of something. It helps you to learn about the symbols if you name them. For example, if a symbol reminds you of a "flower," then name it accordingly, and write the name down next to the stimulus picture on your sheet.

After writing down the names on the piece of paper provided, which contained a coloured copy of stimuli that appeared in each training block, participants pressed the button to proceed to the block of General Training Trials I, and each response was followed by feedback, "correct" or "wrong." Test 2 followed the completion of the training block. It was identical to Test 1, except it used a set of novel stimuli, which were the same ones on the participant's sheet. If participants met the criterion (more than 85% correct, i.e., one error allowed) then they were finished with the experiment. These participants were debriefed and thanked for their participation. If participants did not meet the criterion, then the following "story-making" instruction appeared on the monitor.

> Your aim is to create brief stories that relate the symbols to each other based on which symbols are present and their movement. The procedure for creating a story is as follows: Initially, you are introduced to the first set of symbols, for example, the symbol at the top area (Symbol A) and two separate symbols at the bottom (Symbol B and C) with some movement. You should name the symbols and then create the beginning of a story using parts of speech such as articles, verbs, nouns, adjectives, pronouns. When you are introduced to the different patterns of movement with those symbols and find out which one of the bottom

symbols is the correct choice, you should incorporate it into the story that you have already created, using again some parts of speech as a link.

This process is continued as each new symbol or movement is introduced and associated with the story that you have already created. During the creation of the stories, you should show creativity and imagination in order to incorporate the new symbols and movements into the stories. You are free to create either realistic or fantastic stories. A short example of a story is that a symbol in the top area reminds you of a "sun" and the two symbols in the bottom area remind you of a "flower" and a "cat". The story could be started as follows: "When the sun is there, the flower 'grows' and when the sun is gone the cat 'jumps'; the sun likes the flower." Then, when you see a different pattern of movement of the symbols, you add it to the existing story: "When the sun is there, the cat 'jumps' and when the sun is gone the flower 'grows'; now the sun likes the cat." And so on…

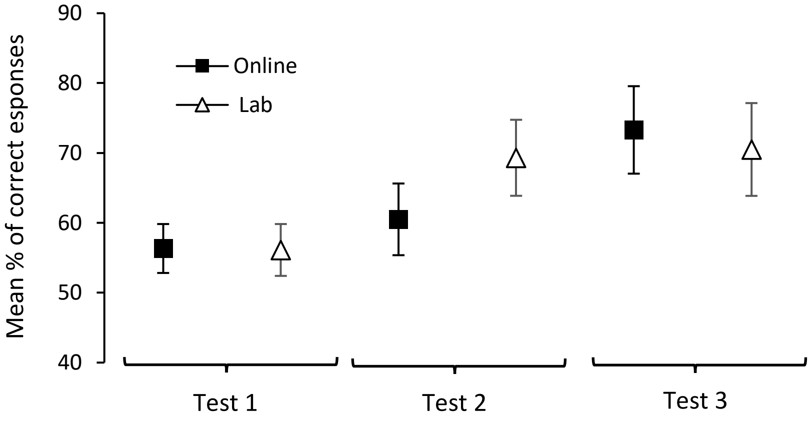
After reading the instructions, participants pressed the button to proceed to General Training II (Table 4). At the end of the training block, a blank field where participants could type in the created story was provided. Participants could repeat the training block up to three times, until meeting the training criteria of 90% correct responses. Participants then proceeded to the last trial, Test 3. Those who did not meet the training criteria after repeating the General Training II three times proceeded to take General Training IV, which was the same training contents provided earlier in General Training I. They could repeat the training block three times, but this time, whether or not they reached the criteria of 85% correct responses, they were able to take Test 3. After completing Test 3, participants were shown the same question as provided in Experiment 1 on the monitor and provided with a textbox to type in their answer. After answering the question, participants were debriefed and thanked for their participation.

Results

The performance of the 18 participants who took the test online in the previous Experiment 1 (Group 1), and the 16 participants who took the test in the experimental room at the university campus in the presence of a researcher on Day 1 in Experiment 2 (Group 2) was similar (Figure 6). We conducted a one-way repeated-measure ANOVA separately for Group 2, using the 16 participants' scores obtained from each test. Using a Greenhouse-Geisser correction based on estimates of sphericity ($\mathcal{E}$ = 0.76), the difference among the mean scores of tests was significant, $F(1.61, 24.21) = 5.21$, $p = .02$, $\eta_p^2 = .26$. Tests of within-subjects planned contrasts indicated that the test scores significantly improved between Test 1 and 2 ($p < .05$). However, there was no significant improvement in the test scores between Test 2 and Test 3 ($p = .74$). This result indicates that participants who did well in terms of their overall test scores improved after the first set of training blocks. On a side note, as the participants were not randomly assigned to groups, no statistical analysis was conducted to compare the mean response accuracy of the two groups.

Figure 6

Comparison of Mean Percentage of Correct Responses between Online vs. Lab Experimental Conditions



Note. The error bar represents standard errors of the mean.

Table 5

Percentage of Correct Responses for the Three Tests and Numbers of Repeated Training Blocks Until Meeting Criteria in Day 1 Experiment 2

Participants	Test 1 (%)	T-A	T-B	GT-I	GT-II	GT-III	Test 2 (%)	T-C	T-D	T-E	Test 3 (%)
1	88	1	1	3	NP	3	88	1	NP	1	100
2	38	1	1	3	3	3	38	1	NP	NP	50
3	63	1	1	1	1	1	50	1	2	NP	63
4	56	2	2	3	3	3	38	1	NP	NP	63
5	44	1	1	2	2	1	56	1	1	2	100
6	63	1	1	2	2	2	69	1	3	NP	25
7	56	1	1	1	-	-	50	1	1	3	100
8	38	1	1	1	1	1	100	2	1	NP	100
9	88	1	1	1	1	1	88	1	NP	NP	50
10	38	1	1	1	1	1	44	1	NP	NP	88
11	63	1	1	1	1	1	88	1	NP	NP	75
12	63	1	1	1	1	-	69	1	NP	NP	50
13	31	1	1	1	-	-	63	1	1	1	100
14	69	1	1	1	1	1	100	6	1	NP	38
15	50	2	1	1	1	-	56	1	NP	NP	88
16	50	1	1	1	1	1	56	5	NP	NP	38
Mean (%)	56.12						65.81				70.5

Note. The table shows a summary of each participant's performance in the three tests (Test 1, 2, and 3) in Day 1 of Experiment 2, plus the number of the repeated training sessions completed until meeting the criteria. Participants whose data are underlined in the table agreed to come back for the Day 2 experiment as a result of their poor test performance. The top column heading represents training sessions in chronological order as the experiment progressed; the abbreviations are all the same as in Table 1. NP means "not passing," indicating the participant did not meet the criteria and carried on to the next training or test trial. A dash [-] indicates that the participant skipped the training trials because they had met the training criteria.

The post-experiment text responses of the participants are summarized in Table 6. The participants who did not do well in Day 1 of Experiment 2 (Participants 2, 3, 6, 9, 12, 14, and 16 in bold italics in Tables 5 and 6) appeared to be confused about what kind of correct answers were expected in the experiment, compared to the participants who did well (for example, Participant 8 who answered succinctly and accurately).

Table 6

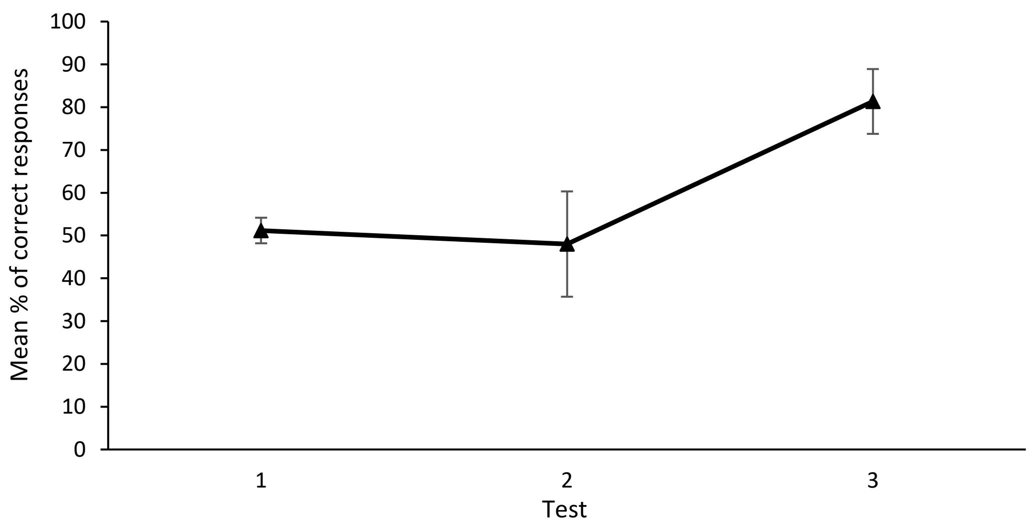
Textual Responses Made by Participants to the Post-experimental Text Questions about How They Achieved Correct Answers

Participants	Textual responses
1	[No answer was provided]
2	***"I thought I had but no, depending on the shapes that appeared I would click* on the shape that flashed before one of the top shapes disappeared**."* [* The participant misunderstood the instruction about not using the mouse while watching the scene with stimuli presentation. The experimenter noticed the frequent "clicking" noise during the experiment and gave the advice to avoid touching the mouse during the experiment.]
3	***"I thought that the correct answers were when one symbol was shown, it correlated with whether I was to select the last symbol I saw or the second to the movement of the last symbol. I found it a bit more confusing with the five symbols but stuck to this same pattern**."*
4	[No answer was provided]
5	"*Yes, I always had to remember the last popped up image that matches to the given stimulus."*
6	"**NO. Is was difficult to know what the pattern was without correction. Essentially, I was thinking about possibilities rather than getting the answer correct when there wasn't any corrections. I could see no obvious pattern in this task.**"
7	"*The object that corresponds to the coloured shape flashes when they are both showing on screen. The correlation between colour and shape can change throughout the clip and the last example shown in the clip is the correct one*."
8	"*Bottom shape that moved last with the top shape."*
9	***"Unsure, but I think it was the last shape that had flashed."***
10	"*The correct answers were correct because there was a pattern that was being followed that led to the right answer. Depending on the shape which blinked, it made the above shape disappear and also reappear. With this, we can come to know which the last move was made. And that was the correct answer."*
11	"*I tried to figure out different rules and test them but the one I eventually settled on was symbols corresponding to another coloured symbol that it 'deactivated'."*
12	"***I figured out that it was either the last shape to move or is one of the other shapes disappeared."***
13	*"I think I figured out why the correct answers were correct. The coloured shape (of which you were asked which blue shape identified with it) needed to be visible while the blue shape(s) went in and out. If the coloured shape was not visible, that blue shape did not correspond to that coloured shape for that in and out."*
14	"***I do not know it**."*
15	"*They were some patterns that followed a sequence. I was able to determine that some shapes were associated with others based on the order they disappeared and reappeared in correlation with the timing of when other shapes blinked. There were some patterns I was unsure of though."*
16	[No answer was provided]

The second aim of Experiment 2 was to examine the effectiveness of the naming and story-making interventions in improving accuracy of responding for those who did poorly in the Day 1 experiment. We hypothesised that the poor performance was affected by the weakness in the relevant stimulus control required to solve the analogous version of the Sally-Anne task, not because of a lack of the particular conceptual component or skill suggested as ToM. Eight of 16 participants (50%) did not increase their response accuracy from Test 1 to 3 (Table 5) in Day 1 of Experiment 2. Seven of the eight participants agreed to come back to participate in the Day 2 experiment. Figure 7 indicates the overall improvement in accuracy from Test 1 to 3 of those seven participants. Analysis of the one-way repeated-measures ANOVA showed that there was a significant main effect on the mean correct responses for three tests, $F(2, 10) = 6.75$, $p = .02$, $\eta_p^2 = .58$. We removed the data for Participant 12 from the analysis because of the higher percentage of correct responses being produced in Test 1 (i.e., this person might have already figured out how to solve the problem before the Day 2 experiment) (Table 7). Bonferroni post-hoc tests on the difference of the mean test scores of the remaining six participants showed that participants did better on Test 3 compared to Test 1 ($p = .03$), but no significant change was observed between Test 2 and Test 1 ($p = 1.00$).

Figure 7

Mean Percentage of Correct Responses of Seven Participants in Day 2 Experiment



Note. The error bar represents standard error of the mean of the percentage of correct responses made for each test.

Table 7

Percentage of Correct Responses for Three Tests and Number of Repeated Training Blocks until Meeting Criteria in Day 2 Experiment 2

Participants	Test 1 (%)	GT-I	Test 2 (%)	GT-II	GT-III	GT-I	Test 3 (%)
2	56	1	25	3	3	1	63
3	50	1	13	1	-	-	88
6	44	1	44	1	-	-	56
9	50	1	56	3	3	1	81
12	94	1	100	1	-	-	100
14	44	1	50	3	1	-	100
16	63	1	100	1	-	-	100
Mean (%)	57		55				84

Note. The table shows a summary of the seven participants' data in Day 2 of Experiment 2. Their performance in each test is presented in the percentage of correct responses, plus the numbers of training trials repeated until each met the training criteria. On the top column heading, GT-1, GT-2, and GT-3 indicate the General Training sessions and are displayed in chronological order (from left to right) to show how the participants progressed through the test and training trials. A dash [-] indicates that the participant skipped the rest of the training trials (until the next test session) because they had met the training criteria and moved on to take Test 2 or Test 3.

The participants' text responses to the naming and story-making interventions are summarized in Table 8. Participants 12, 14, and 16 responded as if the post-experiment question was related to how they got the correct responses, which indicates some improvement because they were all unable to respond correctly to the question on Day 1 of Experiment 2.

Table 8

A Summary of Names and Stories Generated by Participants in Day 2 Experiment 2

Participants	Names for each stimulus appeared in training	Idiosyncratic Stories
2	GT-1 [“Divide” “Book” “Gate”] GT-2 [“Sun” “Vase” “Bird”] GT-3 [“Laptop” Mirror” “Paper”]	*“When the sun appears, the vase with seeds in it will start growing the plant while the bird flies around by the window. Sitting at the desk, the laptop is open with papers beside it and when the laptop closes, I turn to look at the mirror. The papers are pushed aside. When the divided shrinks the book close too and when the divide disappears the gate jumps and sometimes the device reappears.”*
3	GT-1 [“Division” “Blue Gradient” “Grate”] GT-2 [“Flower” “Hourglass” “Star”] GT-3 [“Blue” “C” “Hex” “Burger”]	*“The Flower can appear and disappear as long and often as it likes but when it is present, then the last symbol to shrink and grow is the correct choice. If the flower isn’t present however, then the second to last symbol to shrink and grow is the correct choice.”*
6	GT-1 [“Division sign” “Soap bars” “Files”] GT-2 [“Spark” “Dress” “Boat”]	*“When the dress blinked, the spark disappeared, and the boat blinked but the spark did not appear. When the boat blinked, the spark disappeared, and then the dress blinked but did not appear. Sometimes, the spark could disappear which made the dress blink and the spark would appear and then the boat would blink.”*
9	GT-1 [“Red” “Blocks” “Strips”] GT-2 [“Sun” “Vase” “Arrows”] GT-3 [“Green Triangle” “Circle” “Sheet”]	*“When the arrow moved the sun disappeared, when the arrow moved again the sun appeared, and then the vase moved but the sun stayed. The sun was only affected by the arrow here. When the sun disappeared the arrow moved and then the vase moved, the sun appeared again and then the arrow moved. Here the sun was affected by the vase.”*
12	GT-1 [“Face” “Bars” “Books”] GT-2 [“Sun” “Violin” “Kite”]	*“I chose the shape based on which option flashed in correlation to the coloured shape.”*
14	GT-1 [“Dice” “Bar” “Gate”] GT-2 [“Star” “Water” “Fox”]	*“When the first shape appears, I need to choose the first one that blink and if there is one shape that blink double I will choose the double one.”*
16	GT-1 [“Division” “Double Rectangle” “Equivalent”] GT-2 [“Anger” “Lloyd” “Ace”]	*“I started out with a trial-and-error approach. I mentally created a list of rules and decided to order them by complexity. I started out by testing the simplest rules which happens to be the correct ones. I did not use the shapes names, but instead just identified them based on ‘left’ and ‘right.’”*

Discussion

Half of the participants in Day 1 of Experiment 2 successfully discriminated the basic stimulus pattern required to pass the analogous version of Sally-Anne task. The results were similar to those observed in Experiment 1. It appears unlikely that variables from the online condition affected the participants in Experiment 1. However, a significant increase in accuracy in Experiment 2 was observed between Test 1 and 2, differing to the results of Experiment 1, which showed the increase taking place between Test 2 and 3.

The significant increase in accuracy from Test 2 to 3 among the seven participants on Day 2 of Experiment 2 supported our hypothesis that whether an individual can correctly respond to a perspective-taking task is largely a matter of stimulus control. Our results also support Moustakis and Mellon's (2018) proposition that verbal stimuli may serve as supportive discriminative stimuli, facilitating a participant's stimulus discrimination. The naming intervention did not immediately improve participants' Test 2 performance; however, when participants were prompted to generate stories based on the sequences of training stimulus presentations, their performance improved (from Test 2 to 3). Overall, the self-produced discriminative stimuli may have enhanced participants' discrimination of the designated patterns or relations among the presented stimuli and reinforcers. However, further investigation is required to clarify whether the participants improved their test scores through additional exposures to training trials instead of or in addition to the naming and story interventions.

General Discussion

The current study demonstrated that responding correctly to the traditional Sally-Anne task can be explained by the behavioural process known as conditional discrimination. Behaviour is said to be under the control of conditional discrimination when a particular response reliably occurs in the presence of a stimulus, conditional upon on the presence of other stimuli. The traditional Sally-Anne task examines a child's ability to identify characters appearing in the task (i.e., Sally and Anne as conditional stimuli) and tracks the history of behaviour associated with each character, and any interactions that take place between them and the other stimuli in the experimental context, such as a toy and some containers. For instance, the correct response (e.g., the basket) to a critical question in the Sally-Anne task, “where will Sally look for her toy when she returns?” is under the control of both the confederate (i.e., “Sally”) referred to in the question and the location that the toy was placed (i.e., “in the basket”) when Sally was present in the room. The analogous version of the Sally-Anne task used for the current experiment replicated the stimulus conditions associated with the original Sally-Anne task. The analogous task was presented with various arbitrary stimuli (geometric shapes) to control the pre-established history associated with the familiar stimuli involved in the original Sally-Anne task. The participants undertook a set of training trials that resembled the situation of teaching a person to discriminate the behaviour that people usually look for things in the last place they saw them. Their discrimination learning was then examined through the test trials that were analogous to the original Sally-Anne task. Generalisation of the acquired responses during the training trials was observed during the test phase in both Experiment 1 and 2. Approximately 61% of participants in Experiment 1 and 50% in Experiment 2 increased accuracy across the three tests, responding reliably by selecting the correct conditional stimuli responsible for solving the analogous version of the Sally-Anne task.

We conducted Day 2 of Experiment 2 to explore a different approach to improving the stimulus control of the responses of those participants who did not perform well on Day 1 (i.e., the 50% mentioned above). We provided two types of training interventions adapted from Moustakis and Mellon’s (2018) study, which involved self-generated verbal stimuli used for naming each stimulus and creating a story of how the presented stimuli related to each other. These interventions are said to be based on Skinner’s (1966) idea of constructing discriminative stimuli which specify reinforcement, something especially useful in a context where there is a paucity of stimuli to facilitate effective responding. The act of constructing discriminative stimuli themselves is special because it separates trial-and-error learning from problem-solving behaviour. Moustakis and Mellon defined this chain of operants that alter the probabilities of emission of subsequent behaviour as “intermediate, not mediating; precurrent to solution” (p. 452). We hypothesised that the interventions may have enhanced the discrimination learning for those who did poorly on the analogous Sally-Anne task because they might not have been directly taught how to construct discriminative stimuli as a solution to the problem. In Experiment 2, we observed a significant increase in the accuracy of the test scores among the seven participants who completed the two types of interventions, and the increase in the test scores was clearly shown after the story-making intervention. This resulted in a total of 88% of participants passing the analogous Sally-Anne task in Experiment 2. In our study, the correct responding demonstrated by the participants can be entirely explained by stimulus control, thus the traditional Sally-Anne task may also be explained in similar terms.

There are several limitations to this study. We were unable to provide an explanation for the observed inconsistency in the timing of the increased response accuracy between Experiment 1 and 2. In Experiment 1, the increased accuracy occurred after the training with Type 1 stimulus configurations, but in Experiment 2 it occurred after the Type 2 training. This may be a result of insufficient numbers of training trials for each type of training trial. Therefore, while the type of training we provided may have been adequate, the amount of training may have been insufficient. The information necessary for determining the appropriate numbers of trials could be obtained from conducting additional experiments. Moreover, we could not eliminate the possible influence of the training effects on the outcome of a significant increase in the participant's performance resulting from the naming and story-making interventions in Experiment 2 (Day 2). Setting up a group of participants without having the interventions to control the training effect on the test performance would provide more convincing evidence, but to achieve this a larger number of participants may be required. These aspects need to be addressed in future investigations and research into this area.

Conclusion

Good performance in a perspective-taking task relies on accuracy in predicting the behaviour of others. By examining perspective taking through the lens of "stimulus control," we can more objectively examine the factors affecting a person making an inference about another person's perspective. In the current study, one commonly employed perspective-taking task, the Sally-Anne task, was represented with arbitrary stimuli and relevant stimulus changes that are analogous to the object-transformation depicted in the original Sally-Anne task. We theorised that the analogous Sally-Anne task would help clarify the degree to which fundamental stimulus-control mechanisms can explain accurate performance in such a task. We hypothesised that if our participants demonstrated accurate performance in an arbitrary version of the Sally-Anne task, we could explain performance in the original Sally-Anne task using a similar mechanism without relying on the problematic concept of ToM. To demonstrate that the underlying behavioural process responsible for a correct response in the traditional Sally-Anne task was essentially the conditional discrimination learning that people tend to look for an item where they last saw it, we developed an analogous version of the Sally-Anne task using arbitrary stimuli and measured accuracy of responses in this task. About 60% of the participants in Experiment 1 and half of the participants in Experiment 2 demonstrated behaviour that was under control of the designated conditioned stimuli. After interventions focusing on the self-generated stimuli of naming objects and making a story, accuracy increased, and 88% of participants passed the analogous Sally-Anne task. Behavioural principles can bring more clarity to the understanding of perspective-taking, especially for individuals who are deficient in this skill, and can be used to improve the prediction of another's perspective.

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Appendix A

Generalisation trial components

Trial numbers	presence (P) / absence (A) of a top stimulus (conditions)	Stimulus Movement (“Grow & Shrink”)	Location of bottom stimuli
1	A-P	L-R	B1 (left) B2 (right)
2	A-P	L-R	B2 (left) B1 (right)
3	A-P	R-L	B1 (left) B2 (right)
4	A-P	R-L	B2 (left) B1 (right)
5	A-P	R-R	B1 (left) B2 (right)
6	A-P	R-R	B2 (left) B1 (right)
7	A-P	L-L	B1 (left) B2 (right)
8	A-P	L-L	B2 (left) B1 (right)
9	P-A	L-R	B1 (left) B2 (right)
10	P-A	L-R	B2 (left) B1 (right)
11	P-A	R-L	B1 (left) B2 (right)
12	P-A	R-L	B2 (left) B1 (right)
13	P-A	R-R	B1 (left) B2 (right)
14	P-A	R-R	B2 (left) B1 (right)
15	P-A	L-L	B1 (left) B2 (right)
16	P-A	L-L	B2 (left) B1 (right)

Trial numbers	presence (P) / absence (A) of a top stimulus (conditions)	Stimulus Movement (“Grow & Shrink”)	Location of bottom stimuli
1	A-P-P	L-L-R	B1 (left) B2 (right)
2	A-P-P	L-L-R	B2 (left) B1 (right)
3	A-P-P	L-R-L	B1 (left) B2 (right)
4	A-P-P	L-R-L	B2 (left) B1 (right)
5	A-P-P	R-R-L	B1 (left) B2 (right)
6	A-P-P	R-R-L	B2 (left) B1 (right)
7	A-P-P	R-L-R	B1 (left) B2 (right)
8	A-P-P	R-L-R	B2 (left) B1 (right)
9	A-P-P	L-R-R	B1 (left) B2 (right)
10	A-P-P	L-R-R	B2 (left) B1 (right)
11	A-P-P	R-L-L	B1 (left) B2 (right)
12	A-P-P	R-L-L	B2 (left) B1 (right)
13	P-A-P	L-L-R	B1 (left) B2 (right)
14	P-A-P	L-L-R	B2 (left) B1 (right)
15	P-A-P	L-R-L	B1 (left) B2 (right)
16	P-A-P	L-R-L	B2 (left) B1 (right)
17	P-A-P	R-R-L	B1 (left) B2 (right)
18	P-A-P	R-R-L	B2 (left) B1 (right)
19	P-A-P	R-L-R	B1 (left) B2 (right)
20	P-A-P	R-L-R	B2 (left) B1 (right)
21	P-A-P	L-R-R	B1 (left) B2 (right)
22	P-A-P	L-R-R	B2 (left) B1 (right)
23	P-A-P	R-L-L	B1 (left) B2 (right)
24	P-A-P	R-L-L	B2 (left) B1 (right)
25	P-P-A	L-L-R	B1 (left) B2 (right)
26	P-P-A	L-L-R	B2 (left) B1 (right)
27	P-P-A	L-R-L	B1 (left) B2 (right)
28	P-P-A	L-R-L	B2 (left) B1 (right)
29	P-P-A	R-R-L	B1 (left) B2 (right)

Trial numbers	presence (P) / absence (A) of a top stimulus (conditions)	Stimulus Movement ("Grow & Shrink")	Location of bottom stimuli
30	P-P-A	R-R-L	B2 (left) B1 (right)
31	P-P-A	R-L-R	B1 (left) B2 (right)
32	P-P-A	R-L-R	B2 (left) B1 (right)
33	P-P-A	L-R-R	B1 (left) B2 (right)
34	P-P-A	L-R-R	B2 (left) B1 (right)
35	P-P-A	R-L-L	B1 (left) B2 (right)
36	P-P-A	R-L-L	B2 (left) B1 (right)

Appendix B

Sequential Diagram for Stimulus Presentation of Each Example Training Trial under Training A, B, and General Training I, II, and III

Training A

The below diagram shows an example of a single training trial. In each trial, Stimuli S appeared first in Scene 1, followed by C1, then C2. Then, either C1 or C2 was animated with a "grow and shrink," which marked with [ ] (Scene 2). In the final "Response" scene, selecting the bottom stimulus that moved the last time the S stimulus was present (e.g., C1 as indicated in bold in this case) was reinforced. All responses were given feedback with either the words "correct" or "wrong" appearing in the centre of the screen 1.5 seconds after the response was made.

Scene 1			Scene 2			***Response***		
	S			S			S	
C1		C2	[C1]		C2	**C1**		C2

Training B

Stimuli S appeared first in Scene 1, followed by C1, then C2. After Stimulus C1 showed the animated movement of "shrink and grow" (Scene 2), Stimulus C2 also showed the movement in the same manner (Scene 3). When the "Response" scene appeared, the correct response was selection of the stimulus that last moved when S appeared. In this case, selection of C2 was reinforced with feedback of the word "correct" appearing on the screen. Incorrect responses resulted in the word "wrong" appearing on the screen.

Scene 1			Scene 2			Scene 3		
	S			S			S	
C1		C2	[C1]		C2	C1		[C2]

Response		
	S	
C1		**C2**

General Training – PA trial type

Stimuli S, C1, and C2 appeared one by one in sequential order (Scene 1). After Stimulus C1 showed the animated movement of "shrink and grow" (Scene 2), the S stimulus disappeared (Scene 3). Then, Stimulus C2 showed the same movement (Scene 4). Scene 2 represents the "Presence" as a condition in which the S stimulus appeared. Scenes 3 and 4 represent the "Absence" condition with the absence of the top stimulus. When the "Response" scene appeared, a response was reinforced when a participant selected the stimulus that last moved when S appeared. In this case, selection of the C1 stimulus was reinforced with feedback of the word "correct" appearing on the screen. Incorrect responses resulted in feedback of the word "wrong" appearing on the screen.

Scene 1			Scene 2			Scene 3		
	S			S			-	
C1		C2	[C1]		C2	C1		C2

Scene 4			***Response***		
	-			S	
C1		[C2]	**C1**		C2

General Training – AP type

Stimuli S, C1, and C2 appeared one by one in sequential order (Scene 1). After the S stimulus disappeared (Scene 2), the Stimulus C1 showed the “grow & shrink” movement (Scene 3), which represented the “Absence” condition. In Scene 4, the S stimulus appeared in the top area of the screen, then C2 showed the movement in Scene 5, which represents a “Presence” condition. When the “Response” scene appeared, a response was reinforced when a participant selected the stimulus that last moved when S appeared. In this case, selection of the C2 stimulus was reinforced with feedback of the word “correct” appearing on the screen. Incorrect responses received the feedback of the word “wrong” appearing on the screen.

Scene 1			Scene 2			Scene 3		
	S			-			-	
C1		C2	C1		C2	[C1]		C2
Scene 4			Scene 5			***Response***		
	S			S			S	
C1		C2	C1		[C2]	C1		**C2**

General Training – APP type

This type of trial was a combination of the “Presence” and “Absence” conditions of the presence and the absence of top stimuli while the corresponding bottom stimulus moved. The trial started with the absence pattern, “Absence,” which was followed by the presence pattern of “Presence” that was repeated twice. Then, the participants were exposed to the “Response” scene. In this case, selection of the C2 stimulus was reinforced with feedback of the word “correct” appearing on the screen. Incorrect responses received the feedback of the word “wrong” appearing on the screen.

Scene 1			Scene 2			Scene 3		
	S			-			-	
C1		C2	C1		C2	[C1]		C2
Scene 4			Scene 4			Scene 5		
	S			S			S	
C1		C2	[C1]		C2	C1		[C2]
Response								
	S							
C1		**C2**						

General Training – PAP type

The trial started with the presentation of the target stimulus, which was followed by the absent pattern "Absence," then followed by the pattern "Presence" again. The participants were then exposed to the "Response" scene. Selection of the C2 stimulus was reinforced with feedback of the word "correct" appearing on the screen. Incorrect responses resulted in the feedback of the word "wrong" appearing on the screen.

Scene 1			Scene 2			Scene 3		
	S			S			-	
C1		C2	[C1]		C2	C1		C2
Scene 4			**Scene 4**			**Scene 5**		
	-			S			S	
C1		[C2]	C1		C2	C1		[C2]
Response								
	S							
C1		**C2**						

General Training – PPA type

The trial started with the presentation of the target stimulus, which was repeated twice, then followed by the absent pattern "Absence." The participants were then exposed to the "Response" scene. In this case, selection of the C2 stimulus was reinforced with feedback of the word "correct" appearing on the screen. Incorrect responses resulted in the feedback of the word "wrong" appearing on the screen.

Scene 1			Scene 2			Scene 3		
	S			S			S	
C1		C2	C1		[C2]	C1		[C2]
Scene 4			**Scene 4**			***Response***		
	-			-			S	
C1		C2	[C1]		C2	C1		**C2**

Sequential Details for Type 2 Training Blocks

Training C

An example of a single training trial is shown below. Stimuli S, C1, C2, and C3 appeared one by one, starting from Stimulus S in the order as stated (Scene 1). C1 was animated with the stimulus movement of "grow and shrink" (Scene 2). Then, S disappeared, as indicated by a hyphen below (Scene 3). In the final "Response" scene, selecting the bottom stimulus that moved when Stimulus S was present the last time was reinforced. In this example, selecting C1 was the correct answer.

Scene 1			Scene 2			Scene 3		
	S			S			-	
C1	C2	C3	[C1]	C2	C3	C1	C2	C3
Scene 4			***Response***					
	-			S				
C1	[C2]	C3	**C1**	C2	C3			

Training D

An example of a single training trial. Stimuli S1, S2, C1, C2, and C3 appeared one by one, starting from Stimulus S1 in the order as stated (Scene 1). C1 was animated with the stimulus movement of "grow and shrink" (Scene 2). Then, S1 disappeared and only S2 remained on the monitor (Scene 3). C3 was animated with "grow and shrink" movement while the S2 was still present in the scene (Scene 4). In the final "Response" scene, selecting the bottom stimulus that moved the last time Stimulus S1 was present was reinforced. In this example, selecting C1 was the correct answer.

Scene 1			Scene 2			Scene 3		
S1		S2	S1		S2	-		S2
C1	C2	C3	[C1]	C2	C3	C1	C2	C3
Scene 4			***Response***					
-		S2		S1				
C1	C2	[C3]	**C1**	C2	C3			

Training E

An example of a single training trial. Stimuli S1, S2, C1, C2, and C3 appeared one by one, starting from Stimulus S1 in the order as stated (Scene 1). C3 was animated with the movement of "grow and shrink" (Scene 2). Then, only S1 disappeared and S2 remained on the monitor (Scene 3). C2 was animated with the movement (Scene 4), then S1 re-appeared (Scene 5), and then C3 was animated with the movement of "grow and shrink" (Scene 6). S2 disappeared but S1 remained on the monitor (Scene 7), then C2 was animated with the movement of "grow and shrink" (Scene 8). In the final "Response" scene, selecting the bottom stimulus that moved the last time S2 was present was reinforced. In this example, C3 was the correct answer.

Scene 1			Scene 2			Scene 3		
S1		S2	S1		S2	-		S2
C1	C2	C3	C1	C2	[C3]	C1	C2	C3
Scene 4			Scene 5			Scene 6		
-		S2	S1		S2	S1		S2
C1	[C2]	C3	C1	C2	C3	C1	C2	[C3]
Scene 7			Scene 8			***Response***		
S1		-	S1		-		S2	
C1	C2	C3	C1	[C2]	C3	C1	C2	**C3**

Chapter 5

General Discussion

Reiteration of research problem

Theory of Mind (ToM) has remained a prominent theory for explaining perspective taking as the ability of mental attribution ever since Premack and Woodruff coined the term more than 30 years ago (Call & Tomasello, 2008). However, there is a concern that researchers may have taken the concept at face value, solely focusing research efforts on finding evidence of ToM in both human and non-human subjects (Barrett, 2010; Bolhuis & Wynne, 2009; Cole et al., 2019; Lurz, 2009, 2011; Penn et al., 2008; Penn & Povinelli, 2007; Povinelli & Vonk, 2003; van der Vaart & Hemelrijk, 2014). Many of the experiments conducted in the area of ToM evaluate outcomes in a "Yes" or "No" fashion to determine whether subjects have a certain ToM "cognitive" capacity or ability. The concept of ToM should be scrutinised through a behavioural lens, appealing to principles of stimulus control that have emerged from experimental science. This would allow researchers to examine the concept while minimising assumptions about hypothetical constructs. Researchers seeking to identify the stimulus components and functions involved in perspective taking, and how these components might be learned (and in which order these components are learned most efficiently), are still in their infancy. The primary aim of my thesis was to advance behavioural explanations of ToM. First, I examined existing behavioural theories on perspective taking. I then focused on two specific aspects of perspective taking: the environmental conditions required for a person to engage in deriving someone else's perspective, and how the acquired stimulus functions are generalised to novel contexts. Finally, using one of the well-known false-belief tasks (the Sally-Anne task), I demonstrated that ToM (or other relevant attributions of intention or belief) is not necessarily the main component responsible for an individual responding correctly in this type of perspective-taking task; rather the responses can be explained by a stimulus-control process. My findings and their implications are discussed in chronological order, following how my study developed, followed by a conclusion and recommendations for the direction of future research.

Key findings from the first experiment

In my first experiment I examined the integrity of deictic framing, which proposes deictic expressions (I-You, Here-There, Now-Then) to be the core components of perspective-taking behaviour, as defined in relational frame theory (RFT). To investigate this, I assigned participants into one of three groups: one trained with deictic expressions, another with non-deictic expressions, and a control group. I then measured response generalisation using two different tasks: a visuospatial and an implicit relational assessment procedure (IRAP) task. I hypothesised that significantly higher response accuracy by the group trained with deictic expressions compared to the other two groups would demonstrate the importance of deictic framing in perspective taking. I found that the deictic expressions were non-critical to perspective taking because the performance of the two experimental groups was not significantly different from the control group's performance. Specifically, neither the presence of deictic nor non-deictic expressions in the protocol resulted in response generalisation in the two different perspective-taking tasks. Rather, the performance on each specific task in my study was similar to the performance observed in each of the original studies the tasks were adapted from, which used IRAP and visuospatial tasks, respectively (Barbero-Rubio et al, 2016; Keysar et al. 2003).

Interpretations and implications

In considering the significance of my findings, I concluded that the experimental evidence from my studies suggests that there is a problem with the utility of the BH protocol. The changes in behaviour resulting from training with the BH protocol did not enhance the behavioural outcomes in the other types of perspective-taking tasks, and the training appears to be effective mainly in a similar context as that associated with the BH protocol. The skills learned from the BH protocol may be somewhat restricted in their application, and the protocol is probably not suitable for promoting the best outcomes when flexibility is required to deal with a variety of novel perspective-taking situations. As suggested in Chapter 1, previous studies on the application of distant-transfer tasks (e.g., Level 2 visual perspective-taking tasks, and reality-appearance tasks) reported that the generalisation of ToM performance did not take place (Charlop-Christy & Daneshvar, 2003; Knoll & Chareman, 2000). In addition, limited studies have reported so far that their participants showed generalisation of the skills acquired from BH protocol training over to different ToM tasks. Thus, there is a lack of systematic understanding of the role of stimulus control and generalisation involved in perspective-taking experimental settings. The BH protocol, and the other perspective-taking tasks often used, do not appear to be related to a unitary construct (i.e., ToM). Thus, other approaches to studying perspective taking also need to be re-examined.

Secondly, my findings indicated that there was an issue with the conceptual integrity of deictic framing. Guinther (2017) has already pointed out the theoretical flaw in the concept of deictic framing, with his assertion that deictic words such as I-You, Here-There, and Now-Then do not entail any relational properties. Instead, Guinther developed an alternative model to explain perspective taking (the Relational Triangulation [RT] framework), which suggests how deriving a perspective of another person is contextually controlled. This diverges from the idea of deictic framing, but the conceptual backbone remains within relational frame theory (RFT). Guinther's approach to understanding perspective taking is insightful in that it focuses on the particular behaviour involved (i.e., deriving the perspective of self and others). It is also applicable to much broader contexts for perspective taking, where the behavioural processes involved in derivation could be generalised to different types of perspective-taking situations.

Key findings from the second experiment and implications

In my second study, I evaluated the utility of the RT framework, investigating whether a specific stimulus function with relevant stimuli (i.e., perspective) was derived in accordance with the contextual stimuli that have the relational properties of *same* and *opposition.* This experiment was also presented with inanimate stimuli to control for any influence of pre-established stimulus functions associated with perspective taking. I conducted a between-subjects study to examine the difference in performance between the two groups, one of which was exposed to social stimuli (faces), the other to non-social stimuli (geometric shapes).

One of the key findings was that the derived responses were the result of the contextual control exerted by the specified contextual stimuli of *same* or *opposition* in the experimental context. As the experiment provided minimal explicit visuospatial elements, the derived responding was unlikely to have been influenced by other types of pre-established contextual stimuli. This conclusion was supported by the result, which showed no significant difference in the performance between the groups of participants presented with either social or non-social stimuli. The functionality involved in social stimuli, such as anthropomorphism (i.e., attributing intentions and beliefs to inanimate objects or non-human animals), is still an important aspect (or precursor) in solving perspective-taking tasks. However, the finding that there was no difference associated with the type of stimuli suggests that the observed perspective-taking can be explained as an event with a series of multiple conditional discriminations and possible derivations, which emerged based on the experimentally arranged history of reinforcement with each participating stimulus. The participants' historical experience associated with social stimuli did not appear to facilitate accurate performance during the current experiment.

With this approach to understanding the structural aspect of the RT framework, the current experiment also demonstrated the process of how derived responses were emitted in the context of multiple conditional discriminations acting to form a class of stimuli, leading to transformation of the stimulus functions among the established members of the classes. The results of about half of the participants who performed well in the final test phase provided support for the RT framework, where people derived a perspective of others under the control of the relational stimuli of coordination and opposition. In addition, the participants' responses demonstrated how the different functionality, discriminated through multiple conditional-discrimination procedures, was contextually controlled to establish two classes of "people" stimuli.

Conversely, the data of those who did not do well in the experiment suggested that there was insufficient stimulus control exerted by the designated stimuli and intended functions during the experiment. Even though the responses of participants with poor performance appeared to be under the control of the relational properties of *same*, they were not reliably controlled by the *opposite* relational stimulus. This raises doubts as to the integrity of the claim within RFT that opposite relational framing entails equivalence. The manner in which frames of opposition are acquired, and how equivalence is derived in such frames, does not appear to be as straightforward as implied in RFT. This may require further analysis, such as identifying any other variables that might play a role in the stimulus configurations used in the current experiment (or in previous studies on same and opposite relational framing).

Although my findings from this experiment support the RT framework, the framework itself does not account for many types of perspective-taking behaviour and it may not be sufficient in explaining derived responding under the control of novel contexts (e.g., how do we explain the variability in the derived responses when a person's behaviour is always contextually controlled under a relational stimulus of *difference*?). Additionally, the RT framework may not account for some basic forms of human perspective-taking behaviour (e.g., thinking about what to get for someone's birthday present), or the behaviour observed in non-human animals (e.g., a subordinate chimpanzee successfully demonstrating retrieval of food by inferring a dominant chimpanzee's visual access to the food; Hare et al., 2000). After analysing my experimental findings and reviewing previous research into what accounts for many examples of the perspective-taking behaviours discussed in this paper, I hypothesised that there are some fundamental behavioural processes involved in perspective taking, which go beyond the RT framework.

I therefore conceptualised an approach to examining perspective taking as a type of problem-solving behaviour. There are considerable overlaps between the core behaviours relevant to various perspective-taking and problem-solving tasks, such as accurate recall (e.g., a child sees their friend crying and then acts by giving the upset friend their favourite toy) and subvocal speech (i.e., the self as both speaker and listener) while engaging in the task. For instance, in the previous example, the child might say to themselves "what can I do to make my friend happy?" Although focusing on stimulus-control processes in an attempt to analyse complex behaviour is not new in the field of behaviour analysis, it has not been fully applied to complex behaviour such as perspective taking. The conceptual analysis led me to develop a hypothesis that the Sally-Anne false-belief task (and other perspective-taking tasks) can be understood and analysed solely in terms of the principles of stimulus control. This approach of viewing perspective-taking as problem-solving behaviour is also compatible with an understanding of perspective taking as a non-unitary construct, as problem solving can also be explained with reference to a broad range of behavioural principles.

Key findings from the third experiment

In my third experiment, I focused on a conditional-discrimination process in which the reinforcement for identifying an individual's false-belief depended on a stimulus change in a given setting. The experiment focused on stimulus discrimination of a sequential pattern, a pattern involving the presence or absence of relevant stimuli in the task. In a non-verbal computer task, selection of the bottom stimulus that moved the last time one of the top stimuli was present was reinforced. It was analogous to the traditional Sally-Anne task, in which an accurate response is defined as identifying the location that an object (e.g., a toy marble) was last seen with the target individual. This task replicated the conditional discrimination in a false-belief perspective-taking task, but presented the scenario with only arbitrary stimuli. In Experiment 1, 61% of participants successfully discriminated the pattern of stimulus changes. In Experiment 2, I evaluated the effectiveness of additional naming and story-making interventions by prompting participants to use their verbal repertoires for self-generating supplemental stimuli to increase the accuracy of their responding. After the additional naming and story-making intervention, 88% of participants successfully discriminated the stimulus pattern.

Interpretations and implications

The third study was a direct application of the concept of perspective taking as a type of problem solving for analysing and understanding complex behaviour, focusing on one of the most widely studied perspective-taking tasks, the Sally-Anne task. Although the task was designed to measure young children's false-belief attribution, I hypothesised that the individual responses were in fact dependent on the presence and absence of conditional stimuli in the perspective-taking scenario.

In this approach, the "complexity" of perspective-taking behaviour is determined by the given context, such as the stimulus change in combination with the appearance of specific "person" stimuli, the contiguity and order of stimuli presentation, and the relevant history of reinforcement. These dimensions were experimentally manipulated by the types of exemplars offered in the two sets (Type 1 and 2) of training trials using 10 exemplars (i.e., types of training trials with progressively increasing levels of complexity). The mean percentages of correct responses indicated a significant increase in performance accuracy across the three tests; however, the changes in the performance over the 10 exemplars (i.e., examining whether the discrimination was predictable and orderly) were not consistent between Experiment 1 and 2. The inconsistency was that the increase in accuracy was achieved after Type 2 training in Experiment 1, but after Type 1 training in Experiment 2. Further investigation is necessary to determine the features of training, especially for the predictability and orderliness in the behavioural process, that are most critical to discriminating these types of complex stimulus patterns and movements.

The approach taken in my third experiment might be considered as similar to that taken by Harlow (1947) in conceptualising "learning sets," which propose how one's history of reinforcement affects discrimination learning. It is said that both humans and non-human animals learn effectively in an orderly and predictable manner across exemplars (as opposed to an S-shaped curve indicating a trial-and-error approach), with a progressively increasing rate of correct responses (hence the reduction in the error rate) indicating that "the changes are affected through multiple, though comparable, learning problems" (p. 51). Catania (2013) explained that a learning set can be classified as a higher-order class of operants, because the effectiveness of the learning set is the outcome from one's approach in learning to discriminate "relations" among presented stimuli rather than a trial-and-error approach of stimuli and responses specific to a particular problem. Harlow's experiment involved primates exposed to more than 300 problem exemplars, and the discriminated operant was "if picking up one of the objects is reinforced on the first trial of a new problem, pick that one on all later trials; if it isn't, switch to the other object on all later trials" (Catania, 2013, p. 164).

According to Harlow, such a learning mechanism was consistently observed in the reduction of the error response rate (equally for both young children and non-human primates) throughout a series of exemplars to discriminate an object quality or a positional dimension in the two-item choice problems. The rate at which the participants met the criteria indicated that the human children were faster than the primates, but interestingly both seemed to follow the same observable pattern in their effective learning after the initial stages of "trial-and-error" like responses. One major difference between the children and the primates is the involvement of language with the human children, but this seems to only accelerate the learning time, not alter the behavioural process itself. Thus, while the establishment of the higher-order class may be a predictable outcome that is applicable to both human and non-humans alike, the rate of learning may depend on the additional stimuli available to the person.

The self-generated stimuli used in the naming and story-making interventions in Day 2 of Experiment 2 may have contributed to strengthening the relevant stimulus control, given that the act of constructing the stimuli may specify the reinforcement when there is a scarcity of relevant (or familiar) stimuli available for the emission of appropriate responses. For the experiment, I adapted the instructions developed by Moustakis and Mellon (2018), and used verbal stimuli for the constructed discriminative stimuli. Self-constructed stimuli (e.g., the practice of story-making, naming, belief attribution, or anthropomorphism) can be seen as a socially constructed and adapted practice acquired through a series of interactions with others in a community. This skill (i.e., socially adapted practice) is discussed in the relevant literature in the area of ToM and perspective taking. From a young age, children learn to name inanimate shapes with movements, and even ascribe socially meaningful stories to them (e.g., make-believe play). It has been shown that viewing animated sequences of simple shapes conveys the impression of intentional goal-directed movements for typically developing individuals. On the other hand, shapes that do not move or interact with one another are less likely to support the attribution of mental states. For instance, when children were shown an animation of two geographical shapes (a triangle and a circle) moving in a motion of one following the other, the children reported the event as the triangle “running away” from the circle; when the shapes were shown as making contact with each other, the children reported the shapes as “kissing” (Castelli et al., 2000; Castelli et al., 2002; Heider & Simmel, 1944; Tremoulet & Feldman, 2000; Scholl & Tremoulet, 2000). The act of constructing discriminative stimuli can be considered an important precursor for many forms of perspective-taking.

Thus, as mentioned in the above discussion on Harlow’s (1947) “learning set,” the language element involved in a common perspective-taking task may be considered as collateral stimuli used in solving perspective-taking tasks. The metaphor of “seeing-leads-to-knowing” is often cited as an explanation for children successfully solving perspective-taking tasks. However, placing an emphasis on the language aspect may obscure the underlying discrimination process. Specifically, the naming and story-making interventions may be tacts, a reporting of the reinforcement contingency. My participants were encouraged to name the stimuli, then to make a story that depicted the relations among the presented stimuli. The additional stimuli generated, for example, by naming an unfamiliar stimulus, becomes a discriminative stimulus that evokes selection of the relevant stimuli. Therefore, the participants created stories to specify the reinforcement contingency which could be found in the property of "relations" or "patterns" in the presented sequence of stimulus changes (e.g., I need to see what happened at the bottom of the world when the "sun" stimulus appeared on the top. I picked the "ball" stimulus because I saw that it moved when the "sun" came up). In the original Sally-Anne task, naming one of the confederates "Sally" may make it easier for subjects to recall the relevant stimulus function, such as Sally placing her toy in her basket. Furthermore, the additional descriptions provided for the "Sally" stimulus such as "Sally left the room" and "Sally placed her toy into her basket" may help a participant to attend to the various dimensions associated with the stimulus. To be able to differentiate the various stimulus-features associated with the person stimulus (in this case, "Sally") is important for an accurate response on the perspective-taking task. When an additional description of a change is provided, such as "Anne moved Sally's toy to a box," as it is a more recent event it may have greater stimulus control over the response to the prompt than the other stimulus features introduced earlier (i.e., in such cases the participant is not sufficiently under the stimulus control of the relevant functional stimuli). By considering perspective taking to be a form of problem solving, it can be seen that these verbal stimuli, and other additional stimuli, are part of "effective" discrimination learning (e.g., as opposed to trial-and-error learning) for the emission of appropriate responses when facing an ambiguous situation where there is a lack of appropriate stimuli to respond to. For example, a good poker player constantly watches the body movements of other players on the table to make inferences about what kind of cards their opponents may have. They are not practicing a trial-and-error approach to the game, but rather are keeping track of every card that has been played as well as the behaviour of their opponents. Depending on the stimuli, they will emit a response (e.g., betting "all in" or choosing to "fold"). These are chains of dependent events involving multiple presentations of stimuli with relevant functions, which change every time a dealer deals a new card, or a different behaviour is observed by one of the players. The act of constructing the additional stimuli (e.g., to recall all the "past" and "present" events) would affect the probability of a future outcome and increase the player's chance of winning.

Limitations of the thesis

One limitation of my thesis is that it covers an extremely broad range of methods and concepts rather than focusing on any single aspect of behaviourism. Initially, I intended to conduct an in-depth exploration of the BH protocol and the concept of deictic framing. However, the conceptual issues I encountered, along with the findings indicating that generalisation of perspective-taking skill did not occur, suggested that it would not be fruitful to continue to explore that protocol. From this approach, it seemed that perspective taking was not even a scientific investigation, rather it was something that people "talk" about (i.e., a form of folk psychology). I then delved into the behavioural components involved in perspective-taking tasks, largely because of the RT framework, which provided a plausible experimental direction for understanding this type of complex behaviour. Eventually (after extensive consultation with my advisors), I discovered a useful and novel approach to understanding perspective taking, treating it as a type of problem-solving behaviour. This conceptualisation ultimately led me to conduct my final experiment, which tested the stimulus-control hypothesis and suggested that a false-belief task can be treated largely as a stimulus-discrimination event determined by the variables in the context; it is not dependent on any ToM concept since perspective taking is not related to a unitary underlying construct (e.g., ToM, deictic framing). Advances in understanding the above areas will contribute to our understanding of perspective taking, though such progress is only a beginning. Understanding that perspective taking is not based on a single unitary construct is a step forward, and ongoing conceptual and experimental work will be required to specifically connect these developments with practical applications to perspective-taking behaviour.

Recommendations for future research

Currently, the findings from my final experiment have only been applied to the Sally-Anne task, and additional work needs to be done to further clarify the concept of perspective taking as a type of problem solving. Perspective taking involves the generation of novel behaviour (e.g., imagining, deriving, generating something new), which is an important area of research in the field of behaviour analysis. Humans and non-humans alike emit novel behaviour to solve problems. Instead of finding evidence to support ToM, more effort should be put into understanding the emission of novel behaviour in the context of solving perspective-taking problems (i.e., in dealing with the ambiguity involved in social interactions with others; Holth, 2012; Shahan & Chase, 2002).

Future research on how to increase accuracy in perspective-taking tasks should address the trainability of novel behaviour through operant-conditioning techniques (Neuringer, 2009). Someone skilled at perspective taking most likely has been “taught” how to derive the perspective of others. Evidence of this, even though it was limited, was provided in my third study. Catania (2013) proposed “three sources of novel behaviour” (p.169); one is the reinforcement of behavioural variation through shaping and fading, the second is the emergence of new responses through higher-order classes, and the third is combining classes through an adduction process. Throughout the writing of my thesis on perspective taking in behaviour analysis, I have encountered theoretical problems related to Catania’s second element—how higher-order classes are established. The problem is that multiple behavioural theories co-exist, with equal importance, for explaining the establishment of such higher-order classes. This leads to theoretical divergence, which may be impractical when devising applications for actual behavioural problems, due to the lack of guidance for determining which theoretical approach should be followed and applied.

One major theoretical divergence is the structural approach to understanding higher-order classes (Catania, 2013; Sidman, 1994) compared to the proposed generalised operant focusing on the functional unit of relational responses (RFT: Hayes et al., 2001). There are competing descriptions of the emergence of new responses or classes. For example, in an identity-matching training task for a pigeon, upon a presentation of a red coloured sample, selecting the matching colour of red among other colour stimuli is reinforced. In the same manner, the bird’s responses begin to show discrimination of yellow to yellow, purple to purple, and so on. However, when presented with a novel blue sample, generally a pigeon fails to select blue, even though humans can do the task without much trouble. According to Catania (2013), the behaviour of those who can pass the task is under the control of a higher-order class, which is the one that is generalised across relations over a range of stimuli (e.g., identify matching). Catania’s structural understanding of these competing classes that may be formed through exemplars is that each class (e.g., each specific match defines a class, such as red sample and red comparison) is “embedded” within another class, which is the higher-order class (e.g., identity matching). In the case where the sample and comparison stimuli are all arbitrary, according to Sidman (1994), there has not yet been a universal explanation offered in behaviour analysis as to how children with language difficulty can derive a higher-order class from a reinforcement history with exemplars of paired stimuli that share no features beyond the relation itself. Sidman thought that the emergence of equivalence was based on “fundamental stimulus function” (p. 360). On the other hand, in RFT studies, the behavioural mechanism involved in such derivation of equivalence (or other types of relations such as difference and opposition) is considered to include generalised operants that are contextually controlled relational responses, which are controlled by contextual stimuli such as SAME, OPPOSITE, DIFFERENT, and so on.

The competing theories share the idea that all responses are externally controlled and that there may be other types of relations involved in derived performance (i.e., non-equivalent relations). However, we still need to identify the contingencies that create such higher-order operants, and what controls them. Throughout my experiments, I learned that there does not appear to be a single controlling agent behind this process, but rather varying degrees of stimulus control are involved (it could be a simple conditional discrimination, or a result of contextually controlled higher-order operants, for instance). Research involving non-human subjects can offer some insight to help clarify the core of the debate on the involvement of language or other possible controlling variables involved in the emergence of stimulus equivalence (Lionello-DeNolf, 2009, 2021). In addition, as I suggested in Chapter 2, we may need an alternative explanation to the formation of the class of *opposition* to clarify the structural mechanism involved in the derived response; it could potentially be explained by an equivalence/non-equivalence procedure (Alonso-Álvarez & Pérez-González, 2017, 2018, 2021).

Another major theoretical divergence is the question of whether the deriving response (e.g., higher-order class) can be trained. Studies on stimulus equivalence have provided empirical evidence of non-human subjects demonstrating that the derived response (e.g., symmetry performance) can be strengthened (or discouraged) by the type of training procedure provided (e.g., training on identity relations, controlling position bias and other stimulus dimensions that may have some possible effects; Frank & Wasserman, 2005; Lionello-DeNolf, 2009). For example, a stimulus equivalence study involving California sea lions (Kastak et al., 2001; Schusterman & Kastak, 1993) demonstrated that the animals could be "taught" to derive the relational properties of symmetry and transitive stimulus relations by providing all the prerequisite stimulus relations necessary for the derived responses. The study began in 1988, and it took nearly 4 years for Rio (a female sea lion) to meet the criteria for passing an identity matching task using arbitrary stimuli such as matching A (a crab) and B (a tulip), reversing the relation of B to A, then learning the relations B to C (a radio) and C to B. The reversed BA and CB relations were tested for the emergence of symmetry (with no reinforcement), but Rio was initially unable to demonstrate symmetry. Thus, the stimulus relations used in the symmetry performance tests were established by direct training to a high accuracy criterion (i.e., reinforced probe trials). Once Rio was able to maintain the AB/BA and BC/CA symmetry relations, the transitivity relations CA and AC were trained. In 1992, Rio passed the test with all the relational properties presented with novel stimuli under non-reinforcement conditions.

According to Sidman (1994), Kastak et al.'s (2001) success with derivation is questionable because the sea lion did not perform consistently on the first test of the BA symmetry relation after explicit training of the AB relation. The sea lion's failure in deriving the BA relation in the first test was similar to what has been observed in other studies involving non-human animals, which also showed a failure to derive symmetry relations under non-reinforcement test conditions (Bujedo et al., 2014; Hogan & Zental, 1977; Lionello-DeNolf & Urcuioli, 2002; Sidman et al., 1982). If mere exposure to exemplars is sufficient for nonverbal subjects to be controlled under the generalised concept of symmetry, then the behavioural process responsible for the derivation of the generalised symmetry (or other relations) should be empirically demonstrated as a direct outcome of reinforcement (Sidman, 1994). As stated earlier, Sidman's account on the emergence of stimulus equivalence is based on the fundamental stimulus function; however, considering the possibility that humans may also have been exposed to reinforced symmetry relations from early in life (Dugdale & Lowe, 1990), placing an emphasis on untrained conditions might ignore other possible explanations for the derived responses. To improve the understanding of the process of trainability, it is essential to clarify what component of the exemplars enable the correct derivation of responses in situations with novel stimuli.

There is a similar line of investigation with human participants that focuses on the stimuli produced by behaviour. An emitted response produces stimuli that serve as discriminative stimuli, thus generating a chain of behavioural events (mediated generalization, Eilifsen & Arntzen, 2021; joint control by Lowenkron, 1991, 1996, 1997; Moustakis & Mellon, 2018; Palmer, 2010). For instance, Lowenkron's (1991, 1996, 1997) concept of joint control provides a behavioural account of how multiple control (e.g., Skinner's (1957) definition of "divergent" and "convergent" controls of verbal behaviour) is established through repeated exemplars. The convergent control occurs as a conditional discrimination, in which an auditory stimulus (e.g., the dictated sound "dog") and a non-verbal stimulus (e.g., a picture of a dog) evoke and elicit responses under the form of shared control (e.g., pointing at a picture of a dog). Once the pointing behaviour is established with the pair of stimuli (by going through another set of repeated trials), the same person's pointing response to the written word "DOG" upon hearing the dictated sound of "dog" is reinforced. It is said that divergent control is established when the spoken word "dog" evokes the pointing response to both the picture of a dog and the written word "DOG." Derived relations are observed when the picture of the dog evokes pointing to the written word "DOG" (and vice versa), because the spoken word "dog" and the echoic behaviour (through the repeated exemplar trials) function as joint control (Lowenkron, 1991, 1996; Michael et al., 2011). The "emergence" of a derived response is typically observed when participants evaluate comparison stimuli and select a response that may or may not be reinforced. However, such within-trial events are rarely recorded for analysis. Perhaps the 4 years of training undergone by the Californian sea lion in Schusterman and Kastak's (1993) study may have involved these processes, which resulted in the acquisition of higher-order classes. The concept of Lowenkron's joint control is applicable to the analysis of perspective-taking scenarios, as it can be used to identify the multiple controls established as underlying process for emitting appropriate behaviour.

Other studies focusing on the trainability of derived responding have demonstrated that the transformation of stimulus functions can be achieved using stimulus fading procedures (Braam & Poling, 1983; Cooper et al., 2014). Other researchers have focused more on mediational stimuli (i.e., precursors) which may be involved earlier, before the emission of derived responses or novel behaviour. For example, deriving nonsense syllables such as XYV and BHP in the same class as "apple" through a matching-to-sample procedure is based on the precursor that one can discriminate the nonsense combinations of letters (i.e., showing discrimination of each letter by saying, X, Y, and V, and combining them to form the cluster XYV; Palmer, 1991). Stimulus equivalence is seemingly a natural sequence of behavioural events in human eyes, but there may be a number of building blocks involved (e.g., a series of transformations of stimulus functions) before reaching the point where one can derive untrained stimulus relations.

Considering current technological advancements (for instance, the creation of algorithms based on simplistic models aiming to replicate human behaviour), it is essential that we develop a better understanding of the behavioural mechanisms involved in generating novel behaviour, especially in the area of problem solving. Ideas for how we can understand this novel behaviour include stimulus-generalisation studies, which could be used to demonstrate how perspective-taking tasks can be solved and investigate the extent to which the behavioural processes involved in constructing discriminative stimuli may be relevant to the act of emitting perspective-taking behaviour. Another option is to take a similar approach to Epstein's (1981) pigeon research, where the researcher trained birds with a complex behavioural sequence that seemingly looked like what humans do (e.g., deriving other's perspective), but experimentally the sequence of stimulus presentations was based on a simple algorithm. Developments stemming from the concept of viewing perspective taking as a type of problem solving could be applied to the creation of algorithms for situation-based perspective-taking tasks (i.e., those involving a specific domain that could be defined for artificial intelligence to operate within). This would be important for developing a machine that can work effectively with humans (Labash et al., 2020).

Additionally, for people who have difficulty emitting appropriate responses in perspective-taking situations, viewing perspective taking as problem solving could be of practical help. Rather than perceiving such challenges as unresolvable deficits related to "core" ability, we could instead identify the stimulus components in the context and change the relevant variables to increase the likelihood that the person will emit the appropriate response in the given environment (e.g., when working with others). For example, challenges with social interactions and social situations observed with people with autism are often related to the level of stimulus control with social stimuli (e.g., avoidance of human eyes; Hadjikhani et al., 2017, or over-selectivity; Ploog, 2010). When troubleshooting perspective-taking deficits, a focus on antecedent stimuli can be more practical than trying to assess whether or not an individual has the ability of ToM.

Conclusion

Perspective-taking is an ability of critical importance for a variety of human behaviours, including building relationships, negotiating, and predicting the actions of others. In the study of perspective taking across various fields, the concept of ToM has been the most prominent account for this behaviour. My thesis proposes a behavioural explanation for the concept of ToM, focusing on identifying the stimulus components and functions involved in perspective taking, and how these components might be learned. First, I explored existing behavioural theories on perspective-taking. In the field of behaviour analysis, there have been a small number of empirical studies demonstrating response generalisation—an emission of untrained responses that are functionally equivalent to the trained target behaviour—in various training or testing schemes developed to test an individual's ToM abilities. I investigated the utility of the concept of deictic framing, which was developed as a protocol for training and assessing ToM ability and is posited as a core property of perspective taking in relational frame theory. However, the results from my first experiment suggested that deictic expressions are non-critical to perspective taking. In my second experiment, I evaluated the broader applicability of the relational triangulation framework proposed by Guinther (2017, 2018), who presented the idea that each perspective is derived through the process of relational responding. This approach is a divergence from the deictic framing approach to understanding perspective taking. Guinther's approach was based on identifying specific stimulus functions involved in successful perspective taking and examining how those functions can be established and governed by one's external context. The results from my second study provided further support for this framework, and also raised important questions about the nature of perspective taking and the potential interactive role between the fundamental behavioural processes and higher-order relational processes involved. Through these studies, I conceptualised a new approach which involves applying the analytical tools used to analyse problem solving to perspective-taking behaviour. In my final experiment, I directly applied the proposed behavioural approach and demonstrated that the controlling variables responsible for the emission of correct responses on a well-known false-belief perspective taking task (the Sally-Anne task) were established through conditional discrimination learning. This is the first, though admittedly small, piece of empirical evidence to support the proposed approach of viewing perspective taking as a type of problem solving.

Following on from this approach (understanding perspective-taking behaviour as a type of problem solving), there are many possibilities for further research in this area. Firstly, I recommend that more effort is directed towards clarifying some of the existing theoretical approaches related to the structural mechanisms of derived responding. Specifically, we need to identify the controlling variables responsible for the formation of higher-order classes. There does not appear to be a single controlling agent behind this process, rather varying degrees of stimulus control seem to be involved. Research involving non-human subjects can offer some insight to help clarify the core of the debate on the involvement of language or other possible controlling variables involved in the emergence of stimulus equivalence or other relations. Clarification in this area would be directly applicable to practical situations because such derived responding is central to how we make inferences about the future behaviour of others (i.e., perspective taking). Secondly, further research should focus on the trainability of such derived responding. Approaches that assist people with the emission of accurate predictions of the perspectives of others should be developed further. Specifically, we should look to clarify how exposure to multiple exemplars (or conditional-discrimination procedures) can facilitate the formation of higher-order classes. This could significantly improve our ability to train perspective-taking skills.

My contribution to this area of research is to suggest an approach of looking at perspective taking as problem solving, something that has not been attempted before. This approach improves our understanding of the complex behaviour known as perspective taking by explaining it with the principle of stimulus control. Previous explanations of perspective taking have relied on singular, unitary concepts, such as ToM, which have limited practical and theoretical value. Under my proposed approach, perspective taking is more concretely explained as being the result of an increased sensitivity to both the various stimuli in one’s environment, and the stimulus functions exerting control of that behaviour. By advancing the research related to my proposed approach, we can better train people in the skill of responding to these stimuli in adaptive ways for the purpose of accurately inferring the perspective of others.

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Chapter 1, Experiment 1.
Taylor, T., Sargisson, R. J., & Edwards, T. L. (2022). *Deictic framing performance fails to generalise to other perspective-taking tasks.* [Unpublished manuscript]. School of Psychology, University of Waikato.

Nature of contribution by PhD candidate	Taylor developed the research question, designed the methodology, collected and analysed data and sythesised the reseach outcome under the supvervision from co-authors; Taylor wrote the manuscript with advice and feedback from co-authors.
Extent of contribution by PhD candidate (%)	80

CO-AUTHORS

Name	Nature of Contribution
Dr. Timothy L. Edwards	Assisting with development of the research questions and methods; advice regarding analysis and reviewing & editing the manuscript.
Dr. Rebecca J. Sargisson	Providing advice regarding analysis and reviewing & editing the manuscript.

Certification by Co-Authors

The undersigned hereby certify that:

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Name	Signature	Date
Dr. Timothy L. Edwards	[signature]	30 June, 2022
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Chapter 2, Experiment 2.
Taylor, T., & Edwards, T. L. (2022). *Evaluation of the relational triangulation framework: Testing for derivation of the perspective of others under the contextual control of Same and Opposite stimuli* [Unpublished manuscript]. School of Psychology, University of Waikato.

Nature of contribution by PhD candidate	Taylor developed the research question, designed the methodology, collected and analysed data and sythesised the reseach outcome under the supvervision from co-author; Taylor wrote the manuscript with advice and feedback from co-author.
Extent of contribution by PhD candidate (%)	80

CO-AUTHORS

Name	Nature of Contribution
Dr. Timothy L. Edwards	Assisting with development of the research questions and methods; advice regarding analysis and reviewing & editing the manuscript.

Certification by Co-Authors

The undersigned hereby certify that:

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Chapter 3, conceptual manuscript
Taylor, T., & Edwards, T. L. (2021). What can we learn by treating perspective taking as problem solving? Perspectives on Behavior Science, 44(2-3), 359–387. https://doi.org/10.1007/s40614-021-00307-w

Nature of contribution by PhD candidate	Taylor conceptualised the initial idea, then developed it furnter with co-author. Taylor wrote the initial draft of the manuscript, then wrote the manuscript with advice and feedback from co-author.
Extent of contribution by PhD candidate (%)	65

CO-AUTHORS

Name	Nature of Contribution
Dr. Timothy L. Edwards	Assisting the first author with conceptualisation and reviewing & editing the manuscript.

Certification by Co-Authors

The undersigned hereby certify that:

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Chapter 4, Experiment 3.
Taylor, T., Sargisson, R. J., & Edwards, T. L. (2022). Perspective taking is stimulus control: Conditional control by the presence or absence of "person" stimuli in a false-belief task. [Unpublished manuscript]. School of Psychology, University of Waikato.

Nature of contribution by PhD candidate	Taylor developed the research question, designed the methodology, collected and analysed data and sythesised the reseach outcome under the supvervision from co-authors; Taylor wrote the manuscript with advice and feedback from co-authors.
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