PSYCHOLOGICAL TIME:
THE EFFECT OF TASK COMPLEXITY UPON THE HUMAN ESTIMATION OF DURATION

A thesis
submitted in partial fulfilment
of the requirements for the degree
of
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at the
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SIMON JAMES WEBBER

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ABSTRACT

This thesis was designed to investigate the effect of task complexity upon how humans estimate duration. Previous task complexity research suggests that duration is overestimated with simple tasks and underestimated with complex tasks. One-hundred and forty-two first and second year university students participated. Twelve experiments were conducted, which required participants to complete computer generated jigsaw puzzles and periodically estimate how long they thought they had been doing the puzzle. In Experiment 1, participants were required to complete a jigsaw puzzle before making an estimate. In the remaining eleven experiments, estimates were made throughout the session whilst participants worked on the jigsaw puzzle. In the first four experiments, a task was complex if there were more puzzle pieces and simpler if there were fewer puzzle pieces. There were no significant results obtained from the first four experiments. Given the lack of effect from the first four experiments, the next two experiments partially replicated two task complexity studies to determine how task complexity can be used as an explanation for why estimations of duration differ. Again, there were no significant results obtained from these two experiments. The next four experiments tested whether people's estimates of duration were affected by the rate of reinforcement they receive (i.e., successfully moving a puzzle piece to a new location per unit time). In the first of these two experiments (7 and 8) there was no effect of the manipulation, which consisted of decreasing the distance which a puzzle piece could be moved on the screen, relative to the distance the computer mouse was moved and fixing the speed at which a puzzle piece could be moved. In Experiments 9 and 10, more discriminative stimuli were used to indicate to participants that a change in the reinforcement rate was occurring. There was a significant result in Experiment 9 in one condition but this effect was not replicated in Experiment 10. In Experiment 11, the reinforcement rate was reduced to zero and there was a significant effect on participants' estimates of duration. However, these results suggested a confound between whether the reinforcement rate or not being able to access the jigsaw puzzle was affecting estimates of duration. In Experiment 12, access to the jigsaw puzzle was limited, whilst simultaneously controlling the reinforcement rate and the results showed that not having access to the jigsaw puzzle affected how participants estimate duration. These findings suggest that information can act as reinforcement, enabling a person to engage in private behaviour. When there is no access to reinforcement, time 'drags' for humans.

ETHICS

The Psychology Research Committee of the University of Waikato approved all the experiments conducted in this study. In all of the experiments the participants were required to sign a consent form before the experiment began. All participants were awarded 1 % course credit for each hour of participation, regardless of whether they completed the experiment. Following the completion of each experiment, the participants were fully informed of the purpose of the experiment and given the opportunity to discuss any queries with the Experimenter. The participants were also offered access to the findings of the experiment.

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Thanks to my lab colleague, Richard Etheredge, a.k.a 'Mr Etheredge'. I survived Matlab because of you – cheers bro. Great to hang out with you for the last four years. All the best for your future. Thanks also to my fellow D.A's – Eric Messick, Karen Smith, Trudy Pocock and Rose Black. Been nice going through PhD mill with you all, especially those D.A meetings where Rose grilled me about qualitative approaches to my quantitative thesis! Thanks to Allan Eaddy, Rob Bakker, Ross Oliver and Andrew Malcolm who provided computer technical support. Thanks to Jan Cousens, Joy Fellows and Margaret Brietler, who provided administrative support when I was 'staff' and who tolerated my idle gossip and PhD woes. Thanks to Diane Cordemans, who 'put me up' for some of the time I needed to submit – and a decadent time it was! Thanks to Charles Sitwell, who gave me a stable abode for nine years, whilst I tackled my previous studies and this thesis. Thanks Edo – you know what this acknowledgment means. Finally, thanks to all the students who took the plunge, by signing the recruitment notice to help further the scientific cause.

EDICT

"When a man sits with a pretty girl for an hour, it seems like a minute.
But let him sit on a hot stove for a minute and it's longer than any hour.
That's relativity"

Albert Einstein

DEDICATION

To

The One,

Who,

in the end,

Read and Wrote…

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Psychological Time

The human perception of duration or what is commonly known as ‘psychological time’ (Cottle & Klineberg, 1974; Flaherty, 1999; Fraisse, 1963) is an integral part of life and behaviour (Orme, 1969). Whether waiting for the bus to arrive, being stuck in traffic, having a long day at the office or running to cross the street before the pedestrian light goes off, everyone is affected by how they perceive time to be passing. Flaherty (1999) claims that for humans, when perceiving time, there is some kind of underlying order, in that time can appear to ‘fly’ or it can appear to ‘drag’, irrespective of gender, ethnicity or culture.

Research into psychological time has shown that various factors influence people’s estimates of duration. Several themes have emerged from this research including the amount of attention given to the task (Casini & Macar, 1997; Mattes & Ulrich, 1998), the complexity of the task (Axel, 1924; DeWolfe & Duncan, 1959), the interest in the task (Gray, Gray & Loehlin, 1975; Loehlin, 1959) and the expectation of outcomes (Dube & Schmitt, 1996; Fraisse, 1963). Each of these themes will be reviewed below.

Attention

Mattes and Ulrich (1998) assessed how people’s perception of time is affected by attention to stimuli. There are two theories of how the process of attention might impact on the perception of time. The first is the attenuation hypothesis (Thomas & Weaver, 1975), which states that when attention is given to the stimuli, the duration of stimulus presentation is perceived as longer than when no attention is being given to the stimuli. Thomas and Weaver’s (1975) attenuation hypothesis is based on counting models (Creelman, 1962; Treisman, 1963) which assume that an internal timer or pacemaker within the organism generates pulses which are accumulated during the stimulus interval to be judged. The more pulses that are accumulated during the judging interval the longer is the perceived duration. According to Thomas and Weaver (1975), the number of pulses decreases when attention is given to a nontemporal task, hence the duration of the interval is perceived to be short.

The second theory is the temporal profile hypothesis (Stelmach & Herdman, 1991; Stelmach, Herdman & McNeil, 1994), which assumes that directed attention to a stimulus event shortens the perceived duration. Stelmach et al.’s (1991, 1994) temporal profile hypothesis suggests that temporal-profile or information transmission signals of the visual system are modified by attention to stimuli. This is because the "processing of attended signals occurs at a faster rate than it does for unattended signals" (Stelmach et al. 1994, p 108) resulting in a perception that an event has a short duration.

Mattes and Ulrich (1998) presented two stimuli, the first being a pre-cued stimulus that participants focused their attention on, the second being the target stimulus. Participants were required to press one of three keys to indicate whether they thought the duration of the target stimulus was short, medium or long. Matts and Ulrich (1998) manipulated the amount of time that the pre-cued stimulus was presented and predicted that this would affect the participants' judgement of the target stimulus duration, so that when the longer pre-cued stimulus was presented, the duration of the target stimulus would be estimated as longer. Their results confirmed their predictions and they argued that this supported the attenuation hypothesis.

Casini and Macar (1997) predicted that when minimal attention is given to a temporal task and when there is uncertainty about when a change in stimulus intensity is going to occur, participants will underestimate the duration of a task. Participants were required to perform two tasks. The first was to judge the duration (i.e., short or long) of a visual stimulus being presented. The stimulus was the illumination of a green diode. The second task required participants to indicate whether a change in the intensity of the green diode was 'weak' or 'strong' by pressing one of two response keys at the end of the trial. Thus, participants were required to shift their attention in terms of judging duration to indicating changes in stimulus intensity. Stimulus intensity was changed either early or late in a trial but participants did not know when the change would occur. They only knew it would occur at some point in the trial. Casini and Macar (1997) expected that the participants' uncertainty about when a change in stimulus intensity was going to occur, either during the beginning period or towards the end of the trial, would shift attention away from the temporal task. For example, it was predicted that if stimulus intensity was changed towards the end of a trial, more attention would be focused on trying to detect when a change in the stimulus would occur and therefore less attention would be given to the temporal task, resulting in an underestimation of duration. The results supported this prediction.

Loehlin (1959) investigated different kinds of tasks commonly used in other time perception experiments, such as analogies (Axel, 1924), weight discriminations (Harton,

1938) and puzzles (Rosenzweig & Koht, 1933), which have been shown to influence people's perception of time passing. Loehlin (1959) sought to gain information on how time was perceived for people doing simple and complex tasks and to determine how participants perceived the task (e.g., were they interesting or were they boring). One of Loehlin's (1959) main experimental findings was that attention to stimuli affected the estimation of the duration of filled and empty time intervals. Intervals lacking in content (i.e., empty time) allowed more attention to be given to the empty time interval, resulting in an overestimation of the duration. In contrast, intervals with content (i.e., filled time) resulted in an underestimation of the duration. Whilst it is clear what 'empty' time intervals are and how these intervals can be 'filled', the issue of the degree of 'fill' still needs to be addressed. The following section describes in more detail filled time.

Task complexity

Axel (1924) investigated different activities that can influence people's perception of time. He was interested in classifying the various types of 'filling tasks' in terms of different levels of behaviour based on the complexity of the task. For example, a filling task such as tapping a pencil was classified as a low level behaviour because this type of task is not very complex, whereas a filling task like solving anagrams was classified as a high level behaviour because this type of task is more complex. Participants were required to engage in four different tasks, each varying in the degree of complexity. At the end of each task, the participants were required to record their estimation of the duration of the task.

Axel (1924) found that the duration of the intervals filled with what he classified as 'lower level' activities, such as tapping and writing 'i's, were estimated as being long, whereas the duration of intervals for what he classified as 'higher level' activities, such as solving anagrams, were estimated as being short. Thus, Axel's (1924) general finding was that the durations of more complex tasks were underestimated and the durations of less complex tasks were overestimated.

DeWolfe and Duncan (1959) also tested how the different levels of complexity of a task influence the estimation of duration. In their experiment, three types of tasks were used that corresponded to three levels of complexity. The first task was rest where participants did nothing at all and this was classified as a low-level behaviour. The second task was a reversed alphabet-printing task where participants printed the letters of the alphabet upside down, from right to left. This was classified as medium-level behaviour. The third task was an anagram solving task and was classified as high-level behaviour. A comparison method was used with two conditions, a standard condition, presented first and a comparison condition, presented second. The three types of tasks were randomly presented both in the standard and comparison conditions. Thus, there were nine possible combinations of tasks that could be presented in the standard and comparison conditions (i.e., rest-rest; rest-alphabet; rest-anagram; alphabet-rest; alphabet-alphabet; alphabet-anagram; anagram-rest; anagram-alphabet and anagram-anagram). Participants were required to estimate the duration of the standard condition by doing the particular task in the comparison condition for as long as they thought they had been doing it in the standard condition.

DeWolfe and Duncan (1959) predicted that if a person does a high-level behaviour in the standard condition followed by a low-level behaviour in the comparison condition, then the time spent doing the comparison task should be shorter than the time it took to do the task in the standard condition. Similarly, when a low-level behaviour is presented in the standard condition followed by a high-level behaviour in the comparison condition, the time spent doing the comparison task should be longer than the time it took to do the task in the standard condition. Generally, then, DeWolfe and Duncan (1959) predicted that participants would perceive time as passing faster contingent upon the increasing levels of the standard task during the standard condition and slower with increasing levels of the comparison task during the comparison condition. The results supported this hypothesis.

Smith (1969) also studied how human estimations of duration are affected by the complexity of a task. The method of verbal estimation was used, where participants did the specific task and then wrote down (in seconds) their estimates of how long they had been doing the task. The task was solving analogies and there were three conditions; easy, medium and hard analogies. Smith (1969) found that participants' estimations of duration were affected by the complexity of the task; as analogy difficulty increased, estimations of duration decreased.

Wilsoncroft, Stone and Bagrash (1978) varied task complexity by giving participants two different types of mathematical problems to solve. The first type was a one by one digit problem, which was the easy or low complexity condition. In this condition, randomly selected digits ranging from two to five were used. The second type was a two by one digit problem, which was designated by the researcher to be the hard or high complexity condition. In this condition, randomly selected digits ranging from six to nine were used. An automatic card changing machine presented a card with the digits displayed on it, for either the hard or easy condition. Participants were required to solve the problems. After the presentation of the digit card, a neutral stimulus, a white card with a fixation point, was presented and participants were to leave the white card presented for as long as they thought they had been solving the previous particular problem. By pressing a switch, participants turned off the white card and an unseen timer recorded their estimation.

Wilsoncroft et al. (1978) predicted that participants would overestimate duration when working on the easy tasks and underestimate duration when working on the hard tasks. The prediction was correct for participants doing the easy tasks. However, participants estimations for the hard tasks were not as predicted (i.e., underestimated). In such cases, participants also overestimated duration.

Fraisse (1963) suggested that changes occurring in stimuli are perceived to be more or less 'broken-up', when tasks are comprised of individual units. When each of these units is observed, time seems to 'drag'. For example, a minute seems a lot longer when watching the second hand of a clock mark each of the sixty second units than if one was not watching the second hand. When individual task units are not perceived as broken-up, then changes occurring in the stimuli are not attended to and so the duration of the task is perceived as passing faster than when the units are observed. Fraisse (1963) claims that the underestimation of duration occurs because tasks that are not perceived as broken-up can be described in terms of being 'unified' or having 'purpose'. For Fraisse (1963), purpose, in relation to taking dictation, is "the faithful reproduction of the text" (p 225), which seems to make the individual units of the task less important. However, descriptions of behaviour in terms of purpose are often considered problematic. Chiesa (1994) claims that explaining behaviour in terms of purpose is attributing causal status to future events and that this is not possible. A future event has not happened and may never happen. Hence, it cannot influence present behaviour. Rather, antecedent events influence behaviour. It is unclear then, how a task that has more 'unity' and thus, according to Fraisse (1963), has purpose, can result in shorter estimations of time. Explanations of this kind are problematic, as argued by Chiesa (1994), because they do not indicate any kind of controlling variable influencing changes in behaviour. A controlling variable, influencing a person's estimation of duration for example, would be the complexity of the task and the type of task being used. Fraisse (1963) claims that ‘unified’ tasks are purposeful, and as such, would influence a person’s estimates. It seems that Fraisse (1963) has mistakenly used the word ‘purpose’ as a synonym for ‘unified’, which inevitably leads to superfluous explanations of behaviour.

As previously mentioned, the duration between two events can be occupied by what has been classified as ‘empty time’ and ‘filled time’ (Allen, 1980; Fraisse, 1963). Empty time is a period when there is no presentation of a stimulus. It is the gap or break between the presentations of stimuli; for example, the silence between when one song ends and the next one begins on a compact disc. Filled time cannot be described so easily because definitions vary. It might be described as a period in which stimuli are continually presented, so that there is no break or gap in the presentation (e.g., the presentation of a continuous tone). On the other hand, it can also be described as a period of time filled by behaviour that someone is doing, like digging the garden or a task that a participant may be required to perform in an experiment, like taking dictation. Regardless of the difficulties in definition, the general view is that filled time intervals are perceived as shorter than empty time intervals (e.g., Axel, 1924; Fraisse, 1963; Loehlin, 1959).

Boredom and Interest

As noted before, Loehlin (1959) investigated different kinds of variables which influence people’s perception of time. He used a variety of tasks, such as getting participants to concentrate on time passing, think pleasant thoughts, solve anagrams, take dictation and listen to readings. Participants estimated the duration of each task and rated them as either interesting or boring. One result of Loehlin’s (1959) study was that the participants’ perceptions of duration were influenced by whether they perceived the tasks as either boring or interesting. If a task was perceived as boring, the duration of the interval was overestimated and if it was perceived as interesting the interval was underestimated. This finding suggests a correlation between reports of boring versus interesting and slow versus fast, but to argue that one of these ‘causes’ the other is circular. Does time appear to drag because the task is boring or is the task boring because time drags? This type of circular reasoning does not further the understanding of how humans perceive time relative to the task they may or may not be engaged in.

Gray et al. (1975) studied whether estimations of duration, for participants they rated as being extroverts and introverts, would differ when participants' interests in a task were dissimilar. Eysenck (1957) differentiated extroverts and introverts as being objective and impulsive, and subjective and self-controlled respectively. Gray et al.'s (1975) participants rated several readings, on a 5-point scale, in terms of whether they thought the readings were interesting or dull. The readings were chosen from a pilot study and these readings had been previously judged as interesting, neutral or dull. Participants then judged the duration of how long they thought they had spent reading each particular reading. Gray et al. (1975) found, when comparing both the extroverts' and introverts' mean time estimates for the readings, that there were no differences between the two groups' estimates of duration.

Hawkins and Tedford (1976) examined how the experience of duration is affected by how interesting a task is and by how related particular tasks are. Participants listened to four tapes containing passages from two books on sexuality and human physiology that varied on dimensions of interest and relatedness. They then rated whether the recording was interesting or uninteresting and then judged the duration length of the tape. The interest dimension had been previously established by college students who had rated the passages on sexuality as interesting and the passage on human physiology as uninteresting. On the relatedness dimension, the related tape was a recording of the text as it appeared in the book and the unrelated tape was made up from randomly ordering the words in the text so that the syntax was disrupted.

Hawkins and Tedford (1976) based their experiment on Ornstein's (1975) storage size theory, which states that the experience of duration is directly related to the amount of material stored in memory. Hawkins and Tedford (1976) argued that related items should require less storage and therefore a shorter duration should be experienced. Results did not support the hypothesis, as participants judged the unrelated tapes to be of a shorter duration than related tapes. However, tapes which were rated as interesting were judged to be of shorter duration than tapes which were rated as uninteresting.

<u>Outcomes</u>

Dube and Schmitt (1996) investigated how unfilled intervals (termed empty time) affect estimates of duration within what they called ‘social episodes’. Social episodes are structured social situations that unfold over time. In these situations humans have expectations about obtaining outcomes. For example, visiting a doctor’s clinic, where one ‘checks in’, sees the doctor and then pays the bill on the way out. The social episode can be broken down into three parts or phases. The first is the pre-process phase, which is concerned with the general goal of starting the service transaction (i.e., ‘checking in’ at the doctor’s clinic). The second is the in-process phase, which is the core of the service encounter or the goal of the episode (i.e., seeing the doctor and getting examined). The final stage is post-process phase, where the service encounter is terminated in order to move to another goal (i.e., paying the doctor’s bill and going to another appointment).

To test the effect of social episodes on duration estimates, participants were involved in a study on consumer behaviour. The study used a between-subjects design and the participants received payment at the end of the experiment for participating in the study. There were three groups, one for each of the social phase conditions. Each session lasted for one hour where, in the first part of the session, participants evaluated print advertisements and in the second part they completed two personality scales and an evaluation of the experimental session. A ten minute unfilled interval occurred during each of the three social phase conditions. The unfilled interval was where the Experimenter told participants that he had forgotten some important information and would return shortly after going to retrieve it. Precisely ten minutes after the Experimenter had left a confederate entered the laboratory and asked causally how long participants had thought the Experimenter had been gone. After participants responded to this question, the confederate left and the Experimenter returned, apologising for his absence. For the pre-process phase, the ten minute unfilled interval occurred after the introduction to the experiment, where participants were greeted, told to remove their watches and had the procedure explained to them, and before both parts of the experiment began. For the in-process phase, the ten minute unfilled interval occurred after Part 1 of the experiment was completed but before Part 2 was completed. For the post-process phase, the ten minute unfilled interval occurred after Part 2 of the experiment was completed but before the evaluation and before participants were paid. Three dependent measures were used. The first was the estimate given to the confederate about the ten minute unfilled interval (i.e., how long participants thought the Experimenter had been gone); the second was the estimate given at the end of the experiment about how long the duration of the ten minute unfilled interval was, and the third was an estimate given as part of the evaluation, of whether participants thought the duration of the ten minute unfilled interval had been long or short.

Dube and Schmitt (1996) found that the duration of the in-process phase was overestimated, in comparison to the pre-process and post-process phases. They argued that during an in-process phase, individuals have more specific expectations about obtaining their outcome or goal, as opposed to the pre-process and post-process phases. Previous researchers (Cahoon & Edmond, 1980; Jones & Boltz, 1989; Quingley, Combs & O'Leary, 1984) have shown that during unfilled intervals, where expectation is high about upcoming events (e.g., receiving reinforcement or outcomes, such as getting to see the doctor during Dube and Schmitt's (1996) in-process phase), time has been perceived to pass slower than when there are no expectations about upcoming events (e.g., Dube and Schmitt's (1996) pre-process and post-process phases). When an unexpected delay occurs during the in-phase process it is perceived as longer than the delays during the other two phases. This was because it was presumed that the pre-process and post-process phases were not associated with a higher probability that outcomes will be delivered, thus expectation for the delivery of outcomes is not as high during these phases as during the in-process phase. If the expectation for reinforcement is not so high, such as when one is waiting to see the doctor, the pre-process phase, or after having left the doctor's premises, the post-process phase, then time is not perceived to pass slowly. However, time is perceived to pass slowly at the moment one expects to receive their reinforcement (i.e., seeing the doctor), which is the in-process phase, if there is a delay during this phase.

Fraisse (1963) suggested that people's perception of duration is comprised of elements of frustration and expectation, in that humans become frustrated at not obtaining immediate satisfaction in what they are currently doing (i.e., not being able to obtain an expected or desired outcome). It seems that a comparison is being made between "what is", the unsatisfied current behaviour, and "what will be", the expected outcome (Fraisse, 1963). Fraisse (1963) argues, that "we are not conscious of time when we are fully satisfied with the present situation" (p 206).

It seems then, according to Fraisse (1963), that when an individual is not obtaining outcomes as expected, time is perceived to pass slowly. For example, when catching a bus there is a specified time for when the bus will arrive. It is presumed or expected by an individual wanting to catch a bus that the bus will arrive at the scheduled time. Thus, they would organise themselves so as to be at the bus stop a little bit before the scheduled arrival time. If however, the bus doesn't arrive on time, Fraisse (1963) suggests time will drag because a comparison is possibly being made by the individual about when the outcome should have been obtained (i.e., the persons' expectation that the bus will arrive at the allotted time).

Research Issues

Attention, interest, outcomes and task complexity have been suggested to independently influence the estimation of duration. It is unclear though, how interest and attention can be independent variables influencing the estimation of duration, given that these are descriptive terms only. For example, when an individual is interested in what they are doing, it follows that they are naturally paying attention. It is problematic to explain that a person's perception of duration is the result of interest in and attention to, the particular task they may happen to be doing. These types of explanations are circular and therefore do not explain anything about what influences changes in the estimation of duration (i.e., the independent variable). Interest and attention are aspects of the individual's behaviour and not properties of a task. Thus, it is problematic to suggest that a person's perception of duration changes, when explained in terms of interest and attention, because the variable or the task being manipulated to influence a person's estimation of duration is ignored.

Task complexity as an explanation for changes in a person's estimation of duration is also problematic. Arguing that changes in the estimation of duration are related to whether a task is complex or not, does not adequately explain how differences in estimations of duration are affected by task complexity. What is it about a task that makes it more complex than another task, thereby influencing estimations of duration? What does it mean when there is a change in the complexity of a task? Does task complexity relate in some way to outcomes (i.e., getting things done?) (Lee, 1994). Lee (1994) suggested that the behaviour of organisms could be better understood in terms of 'things done', the "changes that an organism brings about in the world outside itself" (p 17). For example, in Dube and Schmitt's (1996) 'social episodes' study, a person arriving for an appointment with their doctor was seen as obtaining an outcome. Similarly, meeting the doctor and leaving the clinic are also seen as obtaining outcomes. Are then, changes in task complexity a result of obtaining outcomes?

Questions arise about task complexity, with perhaps the most important one being, "what is it"? More research is needed to show how task complexity can be used as an explanation for why estimations of duration differ. This research started by investigating the issue of task complexity in an attempt to show how people's estimates of duration are influenced by the task they may happen to be engaged in.

EXPERIMENT 1

This experiment was the first in a series investigating how a person's estimates of duration are affected by varying an aspect of the task they are engaged in. In previous task complexity studies, the type of task that has been used has varied greatly sometimes within and, almost always, across studies. For example, DeWolfe and Duncan (1959) used anagram and alphabet printing tasks within their study and Wilsoncroft et al. (1978) used mathematical tasks. Thus, no standard task has been used. What was wanted for this present research was a task that humans were familiar with and would do readily and that could be manipulated. Most people have histories with jigsaw puzzles. Jigsaw puzzles can be presented on a computer and therefore, it is possible to vary aspects of a jigsaw puzzle (e.g., size and number of pieces) without varying the basic task. A further advantage of a computer generated puzzle is that it would allow for arranging and recording of experimental events. Not only can aspects of this task be varied but it is also possible to vary such things as the speed with which pieces can be moved. Thus, a jigsaw puzzle that was presented and completed on the computer screen was designed for use in this study.

This first experiment aimed to see whether making a task more difficult would alter a person's estimates of the time they had been engaged with the task. For jigsaw puzzles, the number of pieces the picture is broken into is an easily quantified variable; also completing a puzzle with more pieces takes longer than one with fewer pieces and so the number of jigsaw pieces was manipulated in this first experiment. Task complexity researchers (e.g., Hogan, 1975) have argued that a simple task is where there are fewer stimuli presented and a complex task is where there are more stimuli presented. Thus, in the context of a jigsaw puzzle, fewer puzzle pieces could make the task simpler and more puzzle pieces could make the task more complex. It was hypothesized that participants would give different estimates of duration when there were different numbers of pieces. Two different numbers of pieces were used here and it was expected that fewer pieces (the simple puzzle condition) would lead to longer time estimates for any given time period than when there were more pieces (the complex puzzle condition).

This experiment used the method of estimation to measure perceived duration of the time intervals (Allan, 1979). This procedure has been employed successfully by previous researchers to measure human time perception (Axel, 1924; Craik & Hay, 1999; Loehlin, 1959; Smith, 1969) and requires participants to estimate the amount of time passing, and report this either by speaking out loud or by writing down their estimates. In this experiment, the participants wrote down their estimates.

Method

Participants

The participants were first-year Psychology students at the University of Waikato, New Zealand. They are referred to as P1.1 to P1.15. They were recruited through a notice placed on a notice board in the Department of Psychology. After participation, 1% was credited to their first-year Psychology course. The course credit was received irrespective of their performance in the experiment.

Apparatus

The experiment was conducted in a room, 7 m x 7.8 m, lit by ten fluorescent tubes. Dell OptiPlex GX1 computers were used to control the experimental events. The computer generated black and white jigsaw puzzles of two different dimensions. There were two experimental conditions, one for each of the jigsaw puzzles. In one condition, termed the simple puzzle condition, sixteen jigsaw pieces, four across and four down, each measuring 62 mm x 48 mm, were displayed inside a square, measuring 248 mm x 192 mm on the computer screen at the beginning of the condition. In the other condition, termed the complex puzzle condition, thirty-six pieces, six across and six down, each measuring 42 mm x 32 mm, were displayed inside the square (252 mm x 192 mm) on the computer screen at the beginning of that condition. Figure 1.1 shows the jigsaw puzzle picture, which was used in both conditions throughout the session. A small picture of the completed puzzle, measuring 65 mm x 45 mm, was located in the top left-hand corner of the computer screen in both conditions. It was displayed when the participants moved the pointer over a 'preview' button, measuring 80 mm x 30 mm, that was located to the right of the target picture at the top of the computer screen. Each participant could complete the puzzle by dragging puzzle pieces around with the mouse.

Figure 1.1. Jigsaw puzzle picture.

Procedure

Each of the two conditions was in effect for one half of the experimental session. Half of the participants did the simple condition first and half did the complex condition first. There were 16 pieces in the simple puzzle and 36 pieces in the complex puzzle.

The puzzle was presented several times in each condition and had to be completed each time before it was presented again. In the simple puzzle condition it was presented ten times. This was because pre-experimental tests showed that participants would take about 1 min to complete the simple puzzle. Thus, it was expected to take approximately 12 min to complete the condition. When the participants had completed a puzzle, a small box appeared in the centre of the computer screen, with instructions that read as follows:

> Please enter on the estimation sheet provided, in minutes, seconds or both, your estimate of how long it took you to complete the last jigsaw. Then move the pointer over the 'Continue' button and depress the left mouse button.

The participant then made an estimation of duration before starting the next puzzle, until ten estimates were made, one for each puzzle completed. The condition finished when the participant completed the picture puzzle for the tenth time. Then, if the simple condition preceded the complex condition, a click on the continue button gave the next condition. If the simple condition came after the complex condition the 'Congratulations' screen appeared.

In the complex puzzle condition, the puzzle was presented five times. This was because pre-experimental tests revealed that participants were expected to take about 2.5 min to complete the complex puzzle. Therefore, it was expected that it would take approximately 12 min to complete the complex condition. Thus, both conditions ran for approximately equal 12-min intervals. As in the simple condition, participants used the computer mouse to click on the continue button if the complex condition came before the simple condition. If the complex condition came after the simple condition, the 'Congratulations' screen appeared once the puzzle had been completed. Figure 1.2 shows the display on the computer screen for each phase of the experiment.

At the start of the session, the Experimenter escorted the participants into the computer laboratory. Participants were tested in a group setting but individually. Thus, each participant sat down at a computer and was asked to read the sheet of instructions. The instructions were as follows:

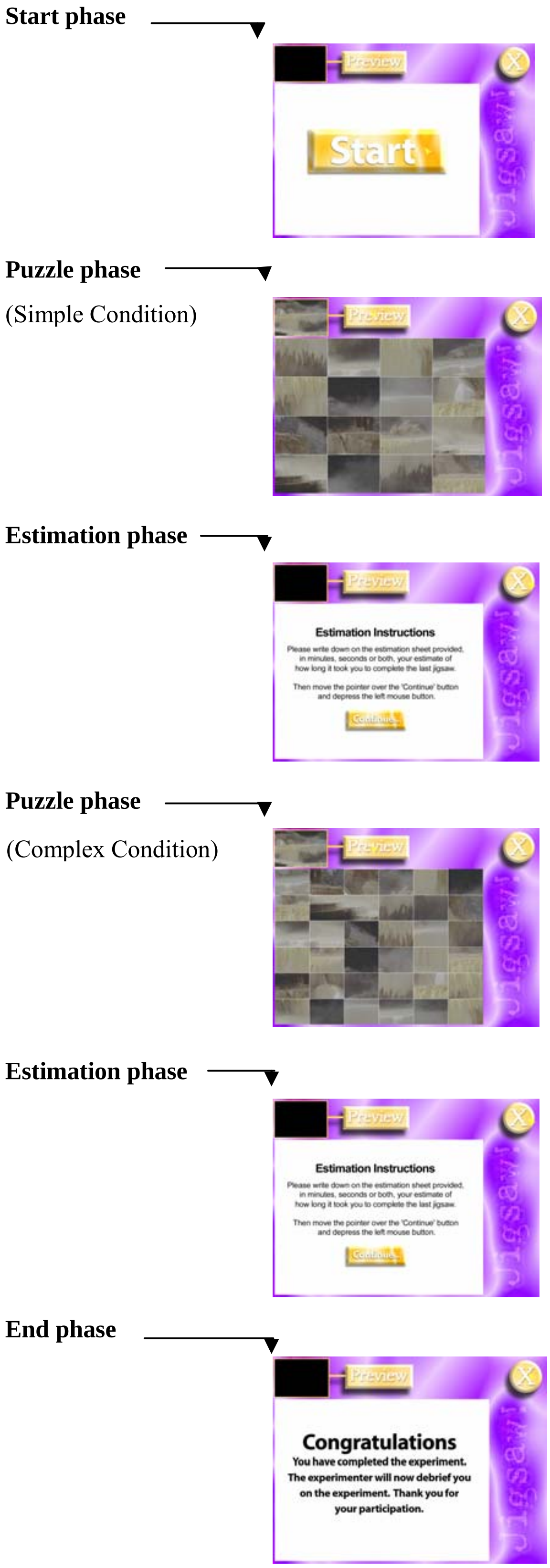

Figure 1.2. Computer screen display for Experiment 1, showing the Start phase, the puzzle phase in the Simple and Complex conditions, and the Estimation and End phases.

Introduction:

This experiment involves working with jigsaw puzzles. The pieces can be moved around to complete a picture. You will be required to complete a puzzle and to estimate how long you thought it took you to complete the puzzle. Please remove your watch and give it to the Experimenter. It will be returned after the experiment. Please read the steps below to familiarise yourself with the experimental procedure.

Step 1: In the experiment, puzzles with sixteen and thirty six square pieces will be displayed on the computer screen. Each of these squares is part of a picture you will see in the top left hand corner of the computer screen. Your task is to use the mouse to move the pointer over a square and depress the left mouse button to drag that square to a new location. You can repeat this until you have completed the puzzle.

Step 2: When the puzzle is completed a box will appear in the centre of the computer screen asking you to estimate how long you thought you spent doing the last puzzle. You may write your estimate in terms of minutes, seconds or both on the estimation sheet provided.

Once you have written down your estimate on the sheet use the mouse to move the pointer over the 'Continue' button situated below the estimation instructions and depress the left mouse button to start the puzzle again. If you have any questions please ask them now. You may start the experiment by using the mouse to move the pointer over the 'Start' button and depress the left mouse button to begin.

Once any questions were answered, the Experimenter asked the participant to remove their watch, if they were wearing one, and informed the participant that it would be returned at the end of the experiment. The Experimenter then told the participant that they could start when ready. The Experimenter remained in the room. No further communication between the Experimenter and the participant occurred until the end of the session. When the participant completed the picture puzzle the fifteenth and final time and had made their estimation, irrespective of the order in which the puzzles were presented, a box appeared on the computer screen, which read as follows:

Congratulations! You have completed the experiment. The Experimenter will now de-brief you on the experiment. Thank-you for your participation.

Once the participant had finished the experiment they were debriefed by the Experimenter as to the aim of the experiment.

Results

There are several ways to present the data from the actual times and the estimates in this experiment. Shown here are the ratios of the estimates of the times to the actual times. These, when presented as logarithms, show the relative degree the estimates differ from the actual times, independently of the absolute size of the time interval being estimated. Thus, for example, the same number results whenever the estimate is twice the size of the actual interval regardless of the length of the actual interval. Logarithmic presentation means that proportionately the same degree of overestimation and underestimation appear as the same size deviation from zero.

Figures 1.3 and 1.4 show the logarithms, taken to the base 10 (both here and elsewhere in the thesis) of the estimates over the actual times it took participants to complete each puzzle in the simple and complex conditions, plotted against the successive number of estimates made throughout the session. All ratios were derived from dividing the estimated times by the actual times, such that a positive measure indicates an overestimation of duration and a negative measure indicates an underestimation of duration. It can be seen from Figure 1.3 that of the 7 participants who did the simple puzzle first, 5 (P1.1, P1.2, P1.3, P1.5 and P1.7) always overestimated duration when doing the simple puzzle. P1.4 overestimated duration on all but the first puzzle in the simple puzzle condition. P1.6 both overestimated and underestimated duration when doing the simple puzzle. In the complex puzzle condition, 4 of the participants (P1.3, P1.4, P1.5 and P1.7) consistently overestimated duration. P1.6 underestimated duration, whereas participants P1.1 and P1.2 overestimated and underestimated duration in the complex condition.

In Figure 1.4 it can be seen that 2 (P1.9 and P1.10) of the 8 participants who completed the complex puzzle condition first, always overestimated duration, whereas P1.12 always underestimated duration. The remaining 5 participants both overestimated and underestimated during the complex condition. In the simple condition, Participants P1.9, P1.11 and P1.15 always underestimated duration. P1.8, P1.10, P1.12 and P1.14 both overestimated and underestimated duration after doing the simple condition. Participant P1.13 generally overestimated duration after completing each puzzle in the simple condition. P1.9, P1.10, P.14 and P1.15 all moved towards underestimating the interval length relatively more over the simple puzzle condition.

A one-way repeated-measures ANOVA was performed, with the manipulation of the complexity of the task as the within-subjects variable and the order in which the task was presented as the between-subjects variable. The ANOVA compared the means of the logarithms of the estimates over the actual times it took participants to complete each puzzle, for both the simple and complex conditions. It was found that there was no significant main effect of complexity (i.e., number of pieces) (F (1, 13) = .510, $p > .05$).

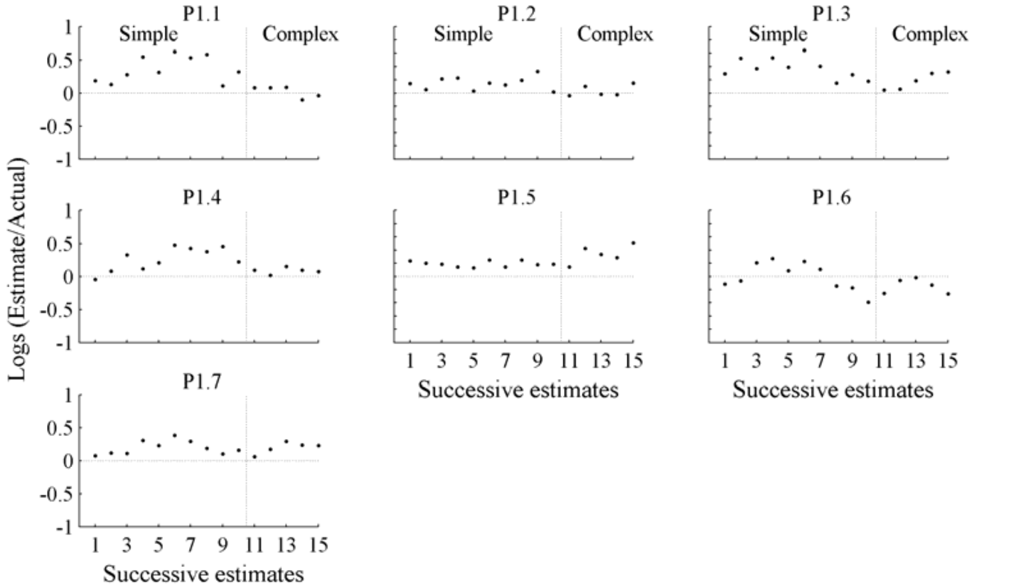

Figure 1.3. Logarithms of the estimates over the actual times in the simple and complex conditions, plotted against the successive number of estimates made in the session, for P1.1 to P1.7.

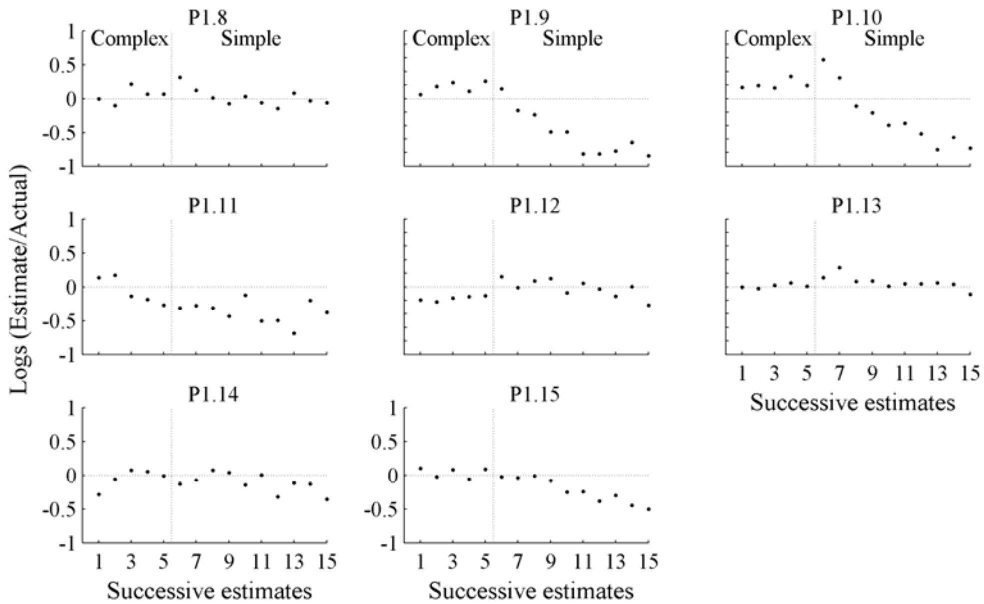

Figure 1.4. Logarithms of the estimates over the actual times in the simple and complex conditions, plotted against the successive number of estimates made in the session, for P1.8 to P1.15.

There was a significant between-treatments effect of presentation order (F (1, 13) = 19.069, $p < .05$) and a significant interaction effect between task complexity and presentation order (F (1, 13) = 7.002, $p < .05$). The effect size for presentation order was medium (η = .595), whereas the effect size for the interaction was small (η = .350). Overall, these data show that the complexity of the task did not affect participants' estimates as expected and that there was an order effect that differed across conditions.

Figure 1.5 shows the estimates of the times and the actual times it took for participants to complete each puzzle in the simple and complex conditions, plotted against the successive number of estimates made throughout the session, for the participants who did the simple puzzle first. These show the size of the interval being assessed and the difference between the two data paths is the amount by which the participants over or under estimated the interval length. It can be seen that the times taken to complete the simple puzzle were very short and that these decreased over the first condition for most participants. The complex puzzle did, as predicted, take more time to complete for all participants and some participants got faster over the condition. P1.1 gave the largest differences between actual and estimated times of all participants in the simple condition, as did P1.5 in the complex condition. P1.3, P1.5 and P1.7 gave estimates close to the actual times in the simple puzzle condition but gave greater differences in the complex puzzle condition. Figure 1.3 shows that these differences did not result in systematic differences in the relative degrees of accuracy. P1.2, P1.4 and P1.6 gave estimates reasonably close to the actual times in both conditions but again the log ratios (Figure 1.3) show no consistent differences in relative degree of accuracy from the other participants.

Figure 1.6 shows the estimates of the times and the actual times it took for participants to complete each puzzle in the complex and simple conditions, plotted against the successive number of estimates made throughout the session, for participants who did the complex puzzle first. Again the simple puzzle was quicker to complete than the complex puzzle. For all of the participants, both the actual and estimated times decreased over the complex puzzle condition and the participants' estimates were generally close to the actual times as the session progressed. Figure 1.4 shows, however, that the small differences between the estimates and the actuals did not result in systematic changes in the relative degrees of accuracy. P1.8, P1.9 and P1.10 generally gave estimates that were longer than the actual times in the complex condition, while the estimates of P1.13, P1.14 and P1.15 were quite close to the actual times in that condition. Figure 1.4 shows that these latter participants were more accurate than the others in that condition. In the simple puzzle

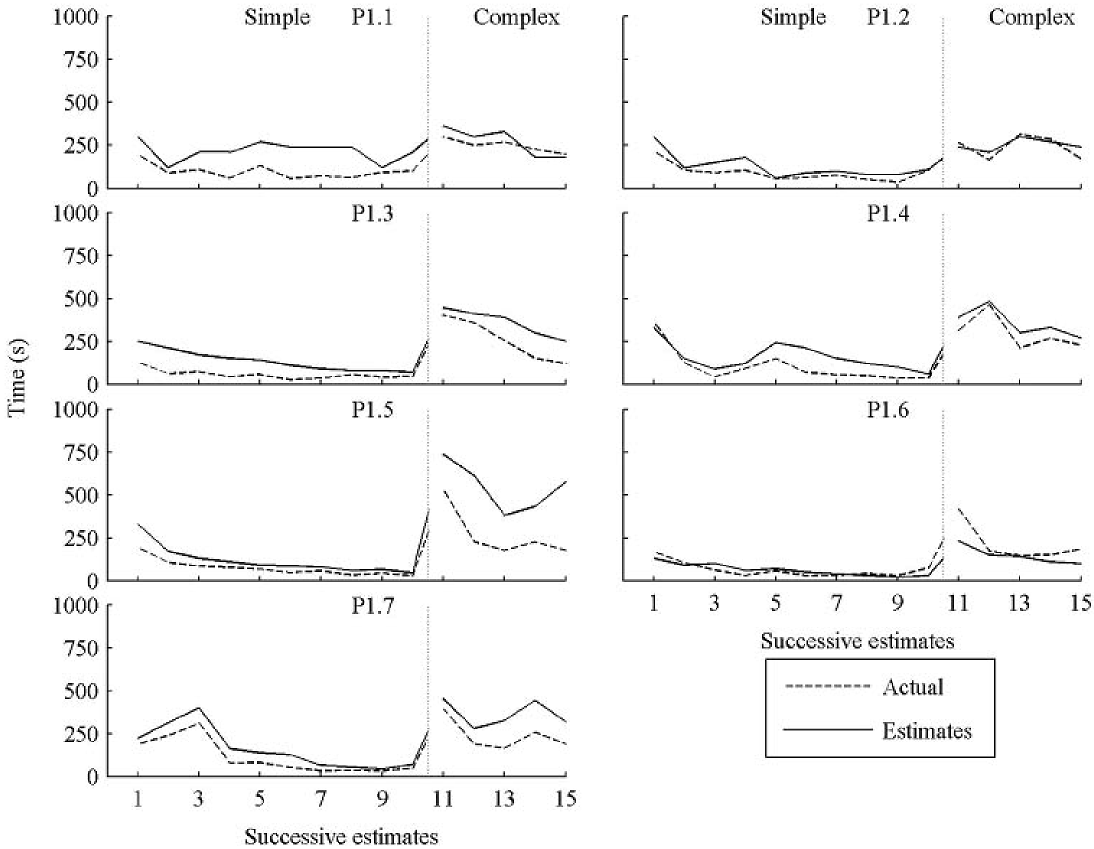

Figure 1.5. Estimated and actual times, in the simple and complex conditions, plotted against the successive number of estimates made in the session, for P1.1 to P1.7.

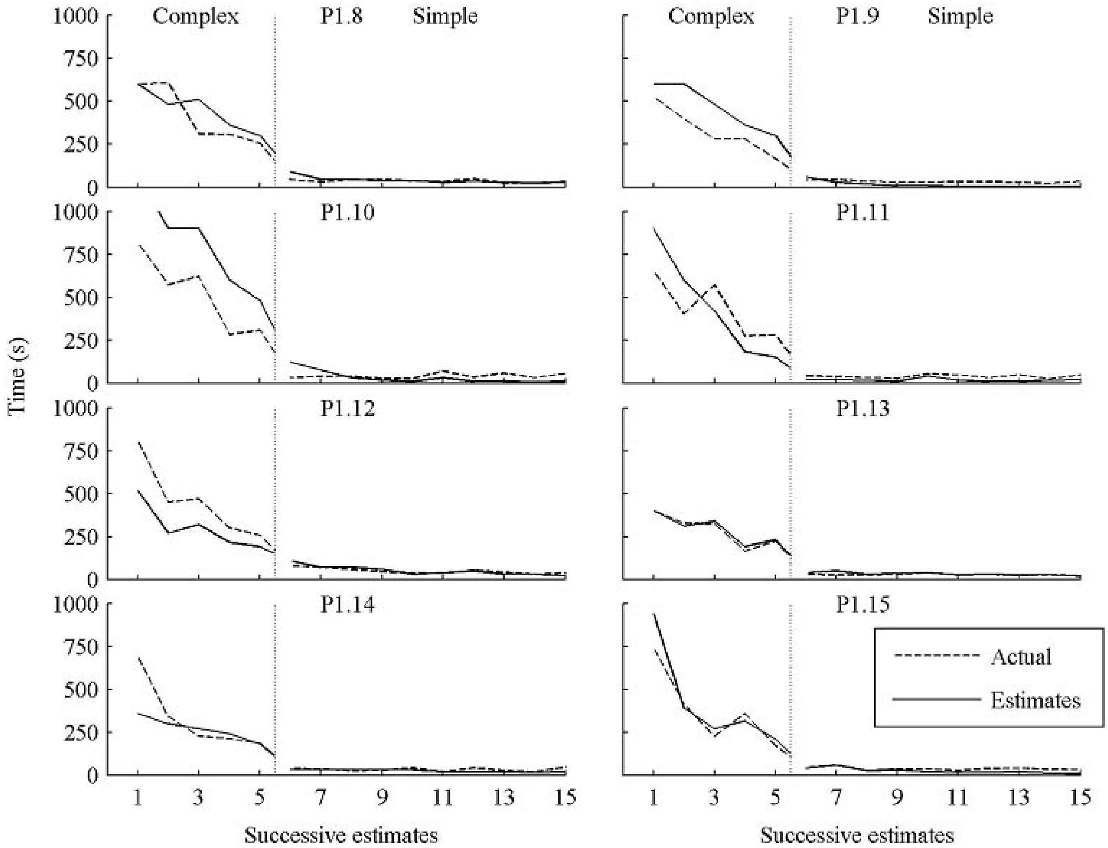

Figure 1.6. Estimated and actual times, in the simple and complex conditions, plotted against the successive number of estimates made in the session, for P1.8 to P1.15.

condition the actual times taken to complete the puzzle were short and all estimates were close to the actual times. The trends seen in the relative degree of accuracy for P1.9, P1.10, P1.14 and P1.15 (Figure 1.4) are not as clearly apparent in Figure 1.6, a product of the fact that small changes in the differences between actual and estimated times have large effects on the log ratios when the actual intervals are short.

Discussion

In this experiment, computerised jigsaw puzzles were used to investigate whether the estimation of the time spent doing the puzzle was affected by the number of pieces in the puzzle. Participants did not estimate duration as predicted from the task complexity literature and there was a clear effect of condition order on the speed of jigsaw completion.

In the results here, the logarithmic ratios show the relative degree of error in estimating the actual time and should be independent of the length of the interval being estimated. Although Allan (1979) argues that it is unclear if the simple version of Weber's law applies to temporal perception, as there was a lack of consistent evidence of this (e.g., Creelman, 1962), she notes that what is clear is that the relationship between durations to be estimated and the estimates themselves, is, in one form or another, proportional. Thus, at longer durations we would expect a larger absolute error compared to a shorter duration. However, the proportional error should be similar irrespective of the absolute magnitude of the duration. Therefore, proportional measures of error, such as the ratios used here, are preferable to simple magnitude measures, particularly where, as in this experiment, the durations being estimated vary markedly in size.

Figures 1.5 and 1.6 show that participants generally became faster at doing the jigsaw puzzle as the session progressed, irrespective of which condition was completed first. This is seen not only in the downward trend in the actual times within participants' data but also across participants, where generally the initial rate of completing the simple puzzle was faster for participants who had already completed the complex puzzle condition and the initial rate of completing the complex puzzle was faster for those who had already completed the simple puzzle condition.

The ratio measures should have allowed comparisons of the estimates from the different durations of jigsaw puzzle completion. One problem, however, was, as the ANOVA showed, there was an effect of condition order on these measures. Figure 1.4 shows that this significant order effect was most likely a product of the increasing degree of underestimation seen over the simple puzzle condition but only when it was second. Participants were completing the simple puzzle very quickly and the actual degree of underestimation was small (Figure 1.6) but did increase over this condition. It is not clear whether the very short times being estimated gave rise to this problem. This order effect confounds interpretation of the present results and it is not possible to separate out any effects of the different durations of the jigsaw puzzle on the estimates from any effects of task complexity.

The next experiment replicated this present experiment with participants estimating after predetermined equivalent intervals in both the simple and complex conditions. The intervals after which participants were required to make estimates were chosen so that they had to estimate the passage of time more frequently than it was estimated in this experiment.

EXPERIMENT 2

The times at which estimates were being made differed between conditions, possibly confounding the results of Experiment 1. This next experiment controlled for any effects of the different times at which participants estimated duration. The control consisted of setting the times at which estimates were made to be the same in both conditions. The times selected ranged between 30 s and 120 s. This range of intervals was selected as it was that used in a task complexity study by Craik and Hay (1999). In that study, there were two groups of participants, older and younger adults, who were required to make estimates of duration using the estimation method or production method. In the present study, as a consequence of setting the durations to be estimated, the session was also of a fixed length and the number of estimates that participants made throughout the session increased compared to Experiment 1.

Method

Participants

The participants were 12 first- and second-year Psychology students at the University of Waikato, New Zealand. They are referred to as P2.1 to P2.12. They were recruited through a notice placed on a notice board in the Department of Psychology and through a brief verbal presentation given by the researcher to them in class. After participation, the first year Psychology students received 1% course credit for their first-year Psychology course. The course credit was received irrespective of their performance in the experiment. Second-year students were not eligible for course credit.

Apparatus

The apparatus was the same as that used in Experiment 1.

Procedure

The procedure was similar to that used in Experiment 1. The differences were that, firstly, when a puzzle was finished another one began immediately. Secondly, the number of estimates that participants had to make was increased. Each session ran for 40 min and was divided into two 20-min periods. There were two conditions, one in each 20-min period. In the simple condition the puzzle had sixteen pieces and in the complex condition it had thirty-six pieces. Half of the participants were presented with the simple condition first and half were presented with the complex condition first. The participants made an estimate of the duration of time that had passed since they made their last estimate whenever prompted to do so by the computer programme. The first estimate in a session was of the time from the start of the session to the prompt for the estimate, whereas all subsequent estimates were of the time from the previous estimate. The participants were asked to make an estimate of the time that had passed four times in each 5-min period; at 30 s, 60 s, 90 s and 120 s. There were eight 5-min periods per session. Thus, participants made 32 estimates throughout the session. These estimates were recorded on the estimation sheet provided. If participants were working on the puzzle when an estimate was requested, the incomplete puzzle was presented again, once the estimate was made, so that it could be completed. If, when the puzzle was completed and no estimate was due, the puzzle was represented immediately.

As in Experiment 1, the Experimenter escorted the participants into the computer laboratory. Each participant sat down at a computer and was asked to read the sheet of instructions. The instructions were as follows:

Introduction:

This experiment involves working with jigsaw puzzles. You can move pieces around to complete a puzzle. Every now and again you will be required to estimate how long you think it has taken you as you've worked on the puzzle(s). Please read the steps below to familiarise yourself with the experimental procedure.

Step 1: In each half of the experiment, a puzzle will be displayed on the computer screen. Each of these squares is part of a picture you will see in the top left hand corner of the computer screen when you move the pointer over the preview button directly to the right of the target picture. Your task is to use the mouse to move the pointer over a square and depress the left mouse button to drag that square to a new location. You can repeat this process as you work on the puzzle.

Step 2: As you work on the puzzle a box will appear every now and again in the centre of the computer screen asking you to estimate how long you think you have currently spent doing the puzzle. You may write your estimate in terms of minutes and seconds or both on the estimation sheet provided.

Once you have written down your estimate on the sheet use the mouse to move the pointer over the 'Continue' button situated below the estimation instructions and depress the left mouse button to start the puzzle again. If you have any questions please ask them now. You may start the experiment by using the mouse to move the pointer over the 'Start' button and depress the left mouse button to begin.

Once any questions were answered, the Experimenter asked the participant to remove their watch if they were wearing one and informed the participant that it would be returned at the end of the experiment. The Experimenter then told the participant that they could start when they were ready. The Experimenter remained in the room. No further communication between the Experimenter and the participant occurred until the end of the session. Once the participant had finished the experiment, they were debriefed by the Experimenter as to the aim of the experiment.

Results

Figure 2.1 shows the logarithms of the estimates over the actual times at which participants were required to make their estimates, for the simple and complex conditions, plotted against the successive number of estimates made throughout the session. Data above the dotted line show overestimation and data below the dotted line show underestimation. It can be seen that P2.1, P2.2, P2.3, P2.6, P2.7 and P2.11 tended to overestimate duration in both conditions. P2.5, P2.9 and P2.10 tended to underestimate duration in both conditions. P2.4, P2.8, and P2.12 underestimated and overestimated duration in both conditions.

A two-way repeated measures ANOVA was performed, with task complexity and time (at which estimates were made) as within-subject variables and the order in which the task was presented as the between-subject variable. The ANOVA compared the means of the logarithms of the estimates over the actual times at which participants were required to make their estimates, for both the simple and complex conditions, and for the actual times at which estimates were made. There was no main effect of complexity (i.e., number of pieces) (F (1, 10) = 2.465, $p > .05$) and the effect size was small (η = .198). There was no between-treatments effect of presentation order (F (1, 10) = .482, $p > .05$) and the effect size was small (η = .046). There was a main effect of the times at which estimates were made (F (3, 30) = 12.055, $p < .05$) and the effect size was medium (η = .547). Pairwise comparisons showed that the log ratios from the 30-s interval were significantly different to those from the other three time intervals ($p <.05$). The analyses also showed that there were no significant interactions between any combinations of complexity, presentation order and the times at which estimates were made, at the .05 alpha level.

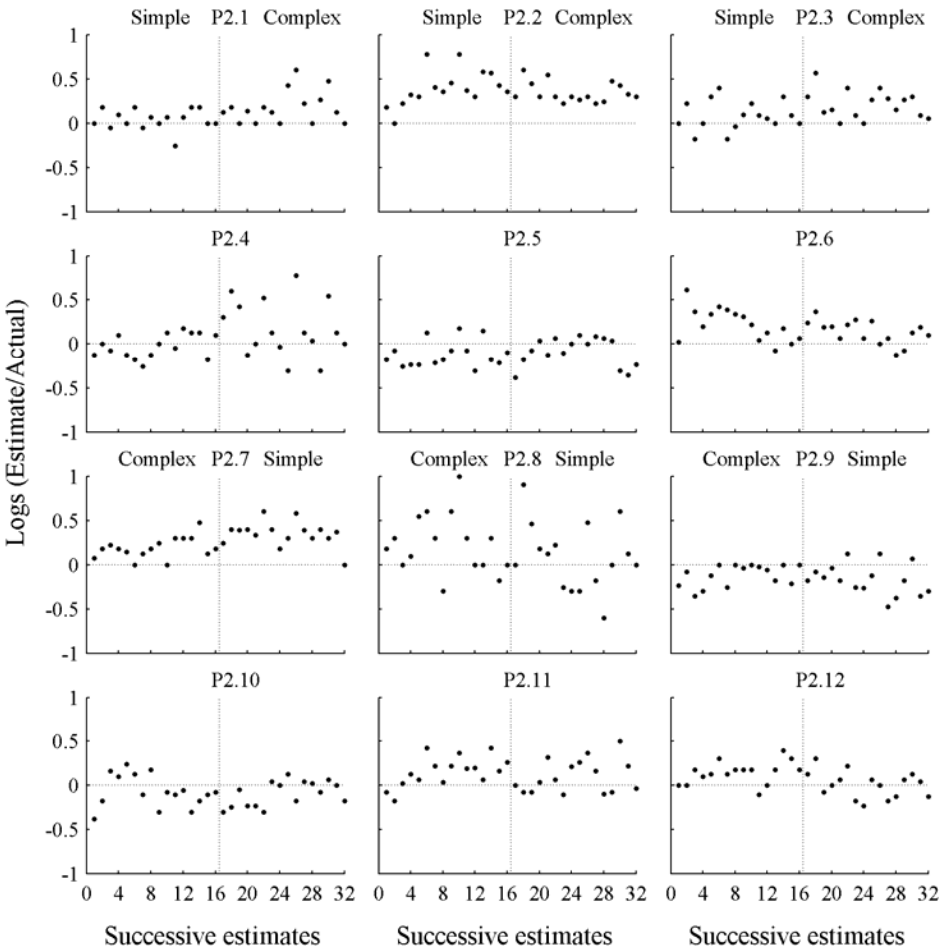

Figure 2.1. Logarithms of the estimates over the actual times in the simple and complex conditions, plotted against the successive number of estimates made in the session.

Figure 2.2 shows the logarithms of the estimates over the actual times estimated, together with the 95-percent confidence interval, for each condition averaged over all participants' data, plotted against the actual times. The asterisks show data from the complex condition and the squares show data from the simple condition. The log ratios show that duration was overestimated at the 30-s and the 60-s intervals, and accurately estimated at the 90-s and 120-s intervals in the simple condition. In the complex condition, duration was overestimated at all interval durations. The log ratios show that estimates decreased in both conditions as the interval at which estimates were made increased. Duration was overestimated more at the 30-s interval in both conditions than for any of the other intervals.

Figure 2.3 shows a plot of the averages of each participant's estimates plotted against the actual times for each condition. The dotted line shows where the estimates would fall if they were completely accurate. Data points plotted above the dotted line indicate overestimation and those below the line indicate underestimation. The asterisks indicate data from the complex condition and the solid circles indicate data from the simple condition. P2.1 through P2.6 completed the simple condition first followed by the complex condition, whereas P2.7 through P2.12 completed the complex condition first. P2.1, P2.2, P2.3, P2.6, P2.7, P2.11 and P2.12 overestimated duration and P2.5 and P2.9 underestimated duration whilst doing the complex puzzle. P2.4 and P2.8 both overestimated and underestimated duration, throughout the complex condition. P2.10 estimated reasonably accurately during the complex condition. In the simple puzzle condition, P2.2, P2.6, P2.7 and P2.11 overestimated duration, whereas P2.5 and P2.9 underestimated duration. P2.1, P2.3, P2.4, P2.8 and P2.12 both overestimated and underestimated duration in the simple condition. P2.10 estimated very accurately in this condition.

Figure 2.3 shows that the participants' estimates generally got larger as the interval to be estimated got longer. If the simple puzzle condition led to greater overestimation of time then the asterisks should generally be below the solid circles regardless of condition order. This was true for only three participants (P2.2, P2.6 and P2.7). The reverse was true for most of the data for remaining participants (a few data points are exceptions, but differences between the estimates in these cases are not great). These data then suggest greater overestimation of time in the complex puzzle condition for many participants.

Figure 2.4 shows the actual times it took for participants to complete each puzzle in the simple and complex conditions, plotted against the number of times the puzzle was

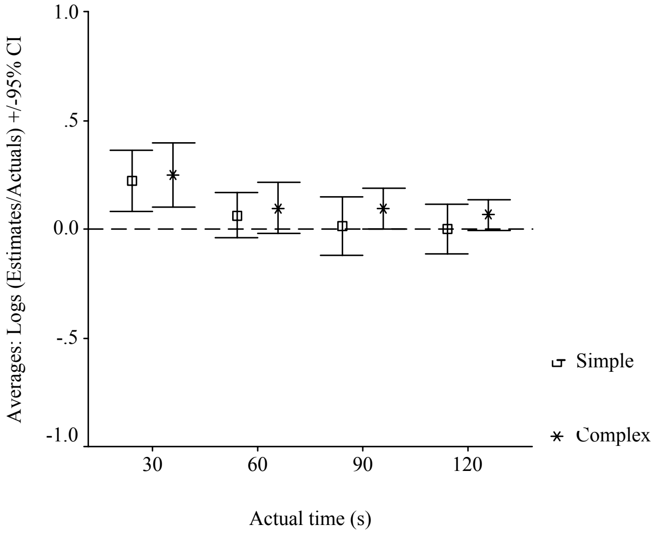

Figure 2.2. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, for each condition, plotted against the times at which estimates were made.

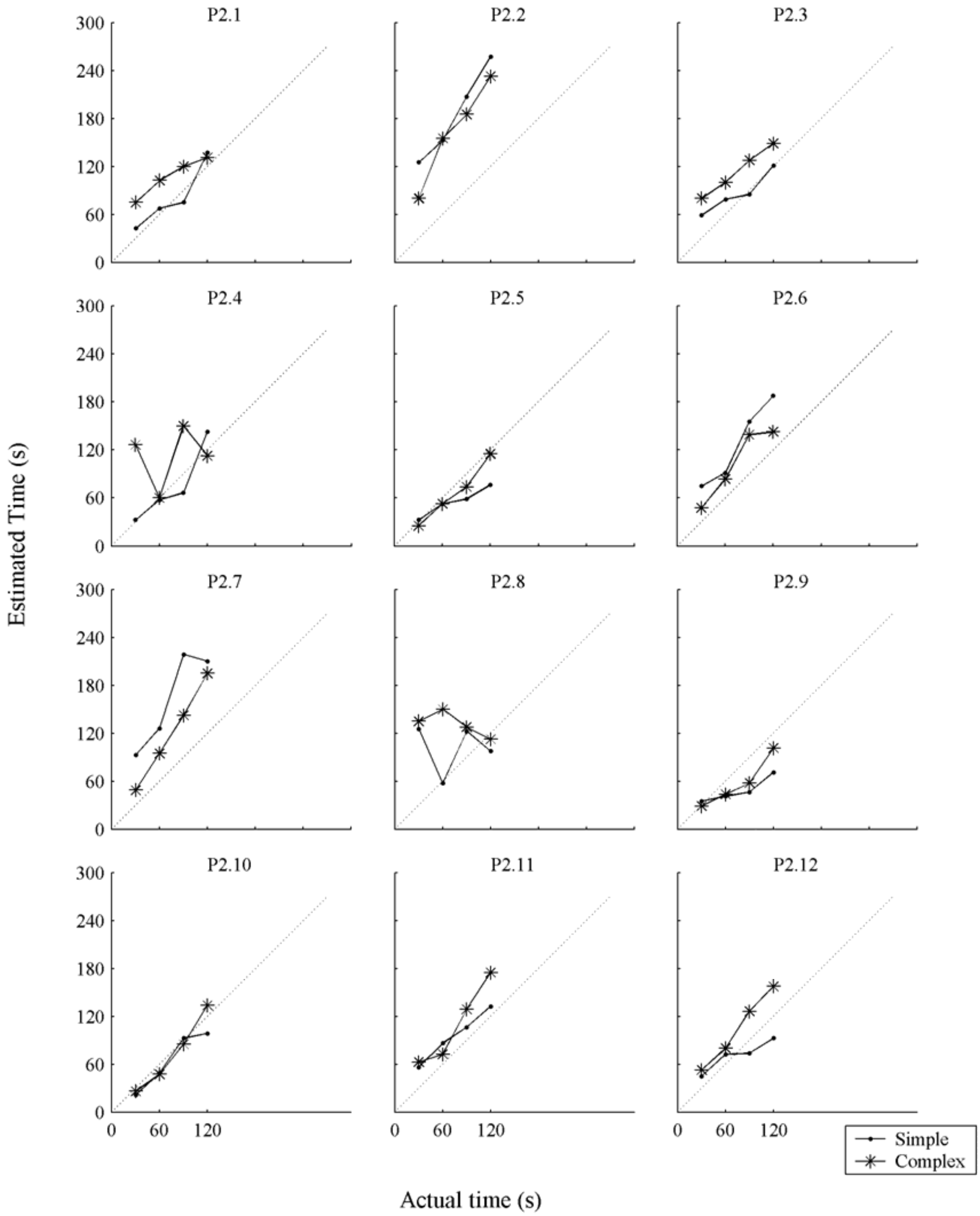

Figure 2.3. Scatterplot averages of participants estimates, plotted against the actual times estimated for each condition.

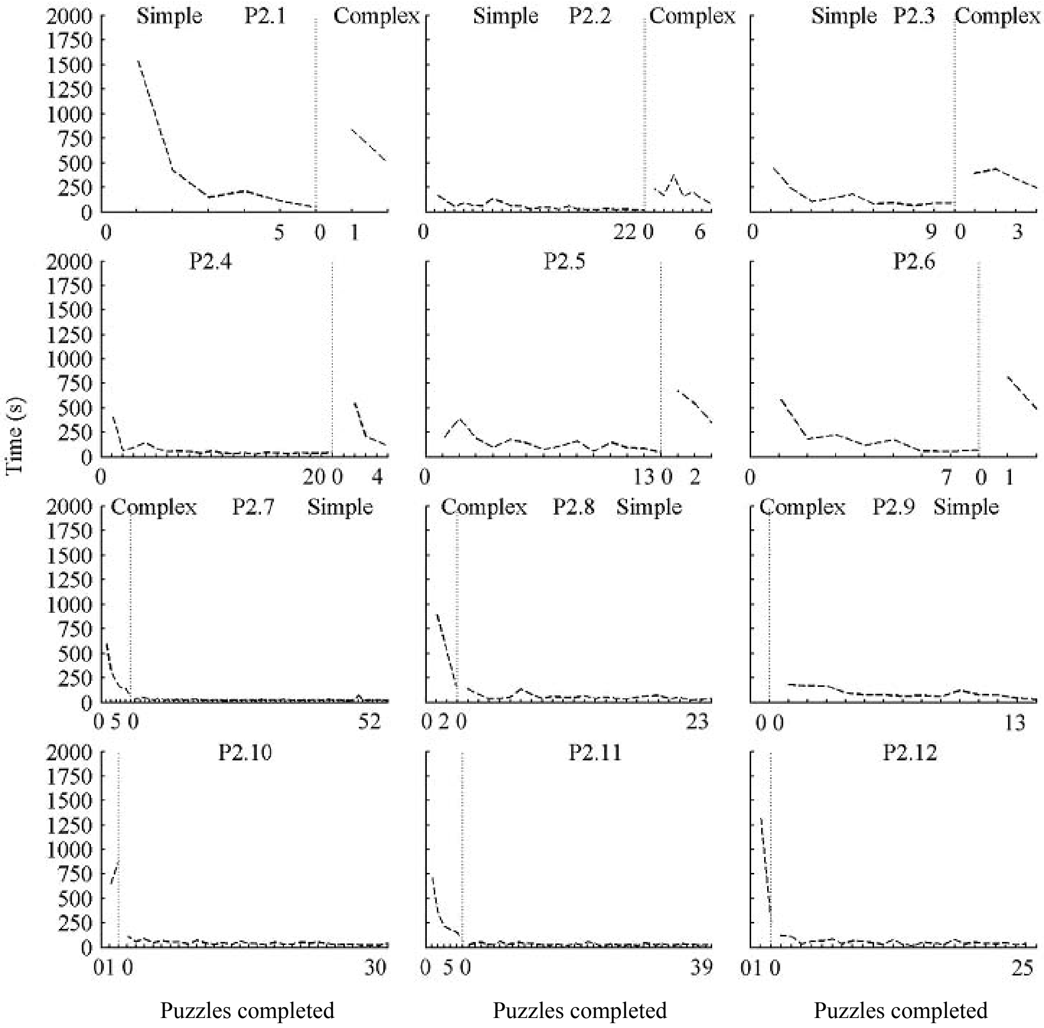

Figure 2.4. Actual times, in the simple and complex conditions, plotted against the number of times the puzzle was completed in each condition.

completed in each condition. This allows for a comparison to be made with the actual times it took participants in Experiment 1 to complete each puzzle in the simple and the complex conditions. Estimates are not included in this figure because estimates were not made at the time the puzzle was completed. P2.1 to P2.6 did the simple puzzle condition followed by the complex puzzle condition, whereas P2.7 to P2.12 did the complex puzzle condition followed by the simple puzzle condition. As the session progressed, all participants generally got faster at doing the puzzle regardless of whether they started with the simple or complex puzzle condition. Generally, across the two groups, the times taken to complete the first puzzle in the second condition were shorter than the times the equivalent complexity puzzle had taken in the first condition. Table 2.1 shows the number of times the puzzle was completed in each condition and the total number of times the puzzle was completed in the session. P2.7 completed the most number of puzzles, whereas P2.1 completed the least number of puzzles.

Discussion

This experiment examined the effect of participants making estimates at set times throughout the session. The results support those from Experiment 1 in showing that there was no consistent effect of the number of puzzle pieces on whether duration was overestimated or underestimated. Thus, the lack of main effect in Experiment 1 was probably not a product of the different times intervals being estimated in the two conditions. The order effect observed in Experiment 1 was not reproduced here. The data in Figure 1.4 suggest that the order effect found there may have been a product of the decreasing log ratios when the simple puzzle condition was second. Figure 1.6 shows that the actual times being estimated in this condition were very short as a result of the participants becoming so much faster at completing the puzzle. Figure 1.6 also shows that there were only small changes in absolute accuracy over the simple puzzle condition. When the actual duration is small, small increases in accuracy give large changes in the ratios. As in Experiment 1, the participants here got faster at doing the puzzle over the course of the session as shown in Figure 2.4. In the present experiment, as in the previous one, the actual puzzle completion times for the simple puzzle condition were shorter when this condition was second. However, unlike the previous experiment, this did not affect the estimates of duration. Taken together these data suggest that the order effect in

Table 2.1. The number of times the puzzle was completed in each condition and the total number of times the puzzle was completed in the session.

Participant	Number completed		Total
	Condition		
	Simple	Complex	
P2.1	5	1	6
P2.2	22	6	28
P2.3	9	3	12
P2.4	20	4	24
P2.5	13	2	15
P2.6	7	1	8
	Complex	Simple	
P2.7	5	52	57
P2.8	2	23	25
P2.9	0	13	13
P2.10	1	30	31
P2.11	5	39	44
P2.12	1	25	26

Experiment 1 may have come from the very short times being estimated in the simple puzzle condition when it was second. The procedure used in the present experiment avoided the changes in the time being estimated and this seems to have removed the order effect seen previously.

As mentioned previously, Craik and Hay (1999) used three intervals at which participants estimated duration. Both groups of participant's estimates, for both estimation methods they used, increased as the interval to be estimated got progressively longer, which is to be expected if judged duration is some constant ratio of actual duration. Participants' estimates in this experiment also increased as the actual times increased and there was a tendency for most participants in this experiment to overestimate duration during both the complex and simple conditions at larger intervals (see Figure 2.3). However, this tendency to overestimate duration was not reflected in the logarithm ratio measures, where in Figure 2.2, participants more accurately estimated duration in both conditions at the larger intervals. As mentioned in Experiment 1, proportional measures of error are preferable to magnitude measures. It might be possible then, as shown in Figure 2.2, that participants found it harder to estimate duration accurately at shorter intervals than at longer intervals. However, it is unclear why at the 30-s interval duration was overestimated more than at the other three intervals. The sequence of the time intervals after which estimates were made in this experiment was 60 then 30 then 90 then 120. Thus, the 30-s interval always followed 60 s. It may be that this influenced the data. The order of the times to be estimated was randomised in the next experiment so as to remove any possible confound of a fixed presentation order.

Craik and Hay (1999) found that task complexity significantly affected estimates of duration in the more complex conditions of the task for the 120-s interval only. A re-examination of the present data (Figure 2.2) shows that, with the 120-s intervals, 7 participants overestimated duration more in the complex puzzle condition than in the simple puzzle condition and 5 underestimated it more in the complex puzzle condition. So it was not the case here that the longer interval gave different results from the shorter intervals.

A difference between Craik and Hay's (1999) study and the present study is that they varied the complexity of the task by getting participants to respond to more than one dimension of stimulus in their most complex condition, whereas the task in the present experiment varied the number of pieces to be moved to create the final picture from 16 to

36 over the two conditions. Craik and Hay (1999) found no effect using between one and four stimulus dimensions but did find one for a 120-s interval using all five dimensions. It could be then, that the present study did not vary the number of jigsaw pieces over a great enough range to affect the task. Therefore, it was decided to vary the complexity of the puzzle by increasing (for the complex puzzle condition) and decreasing (for the simple puzzle condition) the number of pieces in the puzzle in the next experiment.

EXPERIMENT 3

The results from Experiment 2 indicated no effects of the number of pieces upon participants' estimates of duration. In the present experiment the number of jigsaw pieces in the simple condition was decreased and the number of pieces in the complex condition was increased. It was hoped that creating a larger contrast between conditions might result in time being estimated as passing more slowly in the simple condition than in the complex condition. The order of the times at which participants made their estimates was randomised and the puzzle picture was also presented in colour rather than in black and white for ease of viewing.

Method

Participants

Fifteen participants were recruited as in Experiment 1. They are referred to as P3.1 to P3.15.

Apparatus

The apparatus was the same as that used in Experiment 1.

Procedure

The procedure was similar to that used in Experiment 2, but for three differences. First, there were nine pieces in the puzzle for the simple condition and eighty-one pieces in the complex condition. Second, the puzzle was changed from black and white to colour. Finally, the order in which the intervals at which participants were required to make estimates was randomised. As in previous experiments, participants were escorted into the computer laboratory by the Experimenter. The participant sat down at a computer and was asked to read the same sheet of instructions used in the previous experiment. Any questions were answered and the Experimenter asked the participant to remove their watch, if they were wearing one, and informed the participant that it would be returned at the end of the experiment. The Experimenter then told the participant they could start when ready.

The Experimenter remained in the room. No further communication between the Experimenter and the participant occurred until the end of the session, when the participant was debriefed as to the aim of the experiment.

Results

Figure 3.1 shows the logarithms of the estimates over the actual times at which participants were required to make their estimates, for the simple and complex conditions, plotted against the successive number of estimates made throughout the session. For P3.1 to P3.8, the order of the conditions was 'simple/complex', whereas for P3.9 to P3.15, it was 'complex/simple'. P3.2, P3.6, P3.8 and P3.15 overestimated duration in both conditions, whereas P3.9 underestimated duration in both conditions. P3.4, P3.5, P3.7, P3.12 and P3.13 both overestimated and underestimated duration in both the simple and complex conditions. P3.1 overestimated and underestimated duration in the simple condition and overestimated duration in the complex condition. P3.3 overestimated and underestimated duration in the simple condition and underestimated duration in the complex condition. P3.11 overestimated duration in the complex condition and underestimated duration in the simple condition. P3.10 and P3.14 underestimated duration in the complex condition, whilst underestimating and overestimating duration in the simple condition.

A two-way repeated measures ANOVA was performed, with task complexity and time (at which estimates were made) as within-subject variables and the order in which the task was presented as the between-subject variable. The ANOVA compared the means of the logarithms of the estimates over the actual times at which participants were required to make their estimates, for both the simple and complex conditions, and for the actual times at which estimates were made. There was no main effect of complexity (i.e., number of pieces) (F (1, 13) = .042, p > .05) and the effect size was small (η = .003). There was no between-treatments effect of presentation order (F (1, 13) = .953, p > .05) and the effect size was small (η = 0.068). There was a main effect of the times at which estimates were made (F (3, 39) = 6.822, p < .05) and the effect size was small (η = .344). Pairwise comparisons showed that the log ratios from the 30-s interval were significantly different to those from the other three time intervals (p <.05). The analyses also showed that there were no significant interactions between any combinations of complexity, presentation order and the times at which estimates were made, at the .05 alpha level.

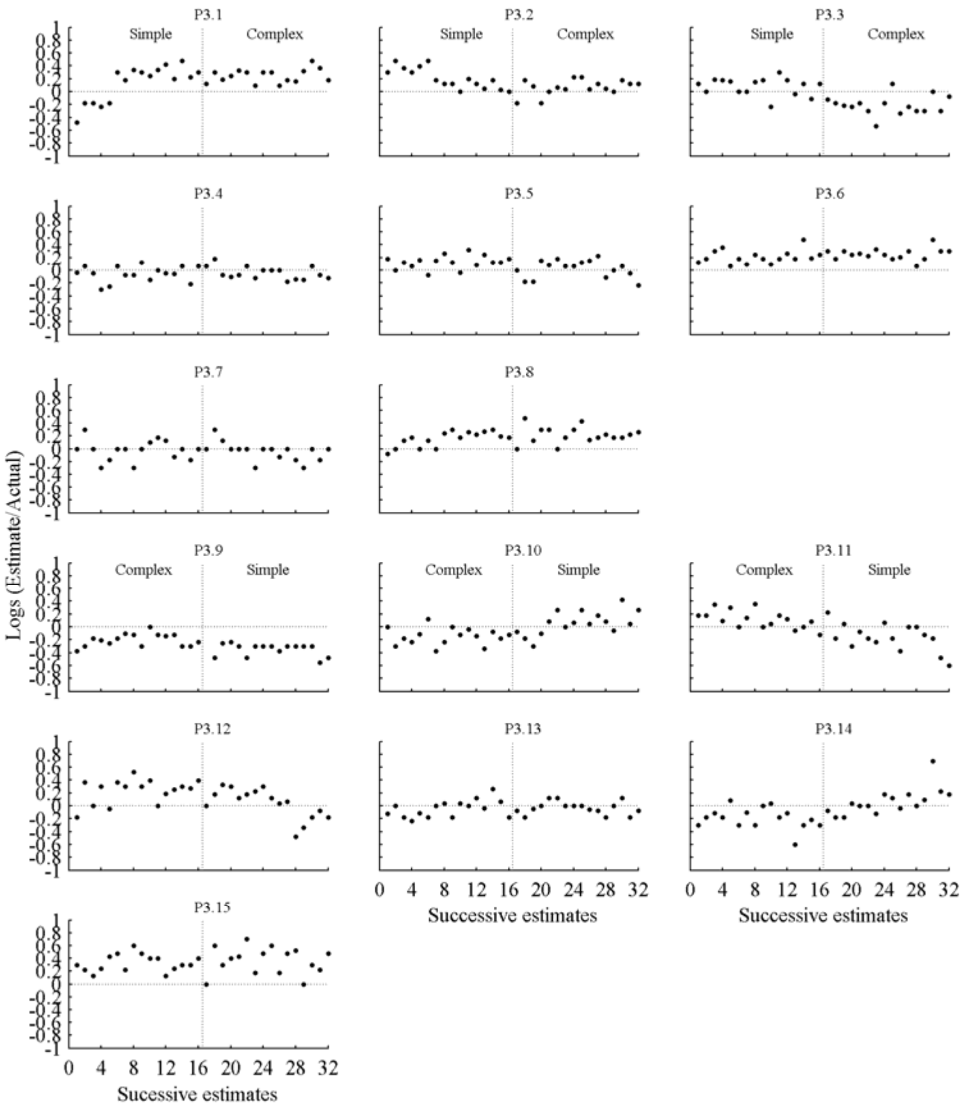

Figure 3.1. Logarithms of the estimates over the actual times in the simple and complex conditions, plotted against the successive number of estimates made in the session.

Figure 3.2 shows the logarithms of the estimates over the actual times estimated, together with the 95-percent confidence interval, for each condition averaged over all participants' data, plotted against the actual times. The asterisks show data from the complex condition and the squares show data from the simple condition. The log ratios show that duration was overestimated at the 30-s and the 60-s intervals in both conditions and accurately estimated at the 90-s and 120-s intervals in both conditions. There were very few differences in the estimates made in the simple and complex conditions. The log ratios of the estimates to actual times decreased in both conditions as the interval at which estimates were made increased. The log ratios also show that duration was overestimated more at the 30-s interval in both conditions than for any of the other intervals.

Figure 3.3 shows a plot of the averages of participants' estimates plotted against the actual times for each condition. The dotted line shows where the estimates would fall if they were completely accurate. Data points plotted above the dotted line indicate overestimation and those below the line indicate underestimation. The asterisks indicate data from the complex condition and the solid circles indicate data from the simple condition. P3.1 through P3.8 completed the simple condition first followed by the complex condition, whereas P3.9 through P3.15 completed the complex condition first. P3.1, P3.2, P3.6, P3.8, P3.11, P3.12 and P3.15 overestimated duration and P3.3, P3.4, P3.9, P3.10 and P3.14 underestimated duration whilst doing the complex puzzle. P3.13 accurately estimated duration in the complex condition. P3.5 and P3.7 also accurately estimated duration in the complex condition, except during the 120-s interval, where P3.5 overestimated duration and P3.7 underestimated duration. In the simple puzzle condition, P3.1, P3.2, P3.3, P3.5, P3.6, P3.8, P3.12 and P3.15 overestimated duration, whereas P3.4, P3.9 and P3.11 underestimated duration. P3.7 and P3.13 accurately estimated duration in this condition. P3.10 and P3.14 overestimated duration at the 30-s and 60-s intervals but were accurate in their estimates at the 90-s and 120-s intervals.

Figure 3.3 shows that participants' estimates generally got larger as the interval to be estimated got longer, as well as decreasing for some participants at the 120-s interval (P3.3, P3.7, P3.10, P3.11 and P3.15). Five participants (P3.2, P3.3, P3.5, P3.10 and P3.14) underestimated duration in the complex condition compared to the simple condition, whereas the reverse was true for P3.6, P3.8, P3.9, P3.11 and P3.12. The data for the remaining 5 participants (P3.1, P3.4, P3.7, P3.13 and P3.15) were variable. These data suggest that there are no consistent differences in the way the estimates deviated from the

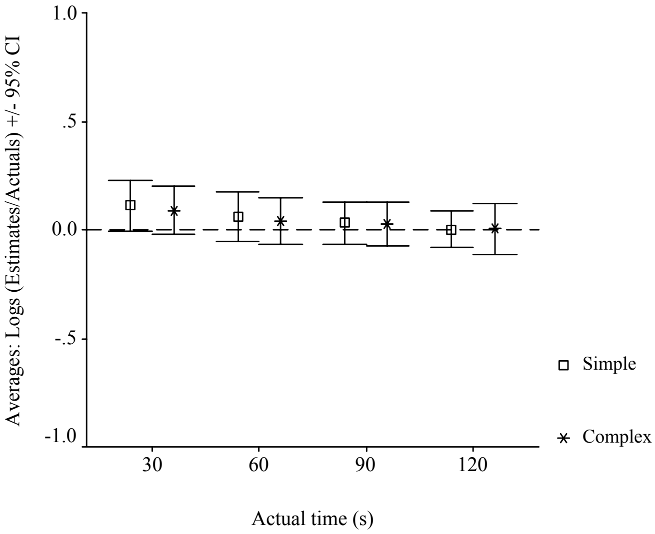

Figure 3.2. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, for each condition, plotted against the times at which estimates were made.

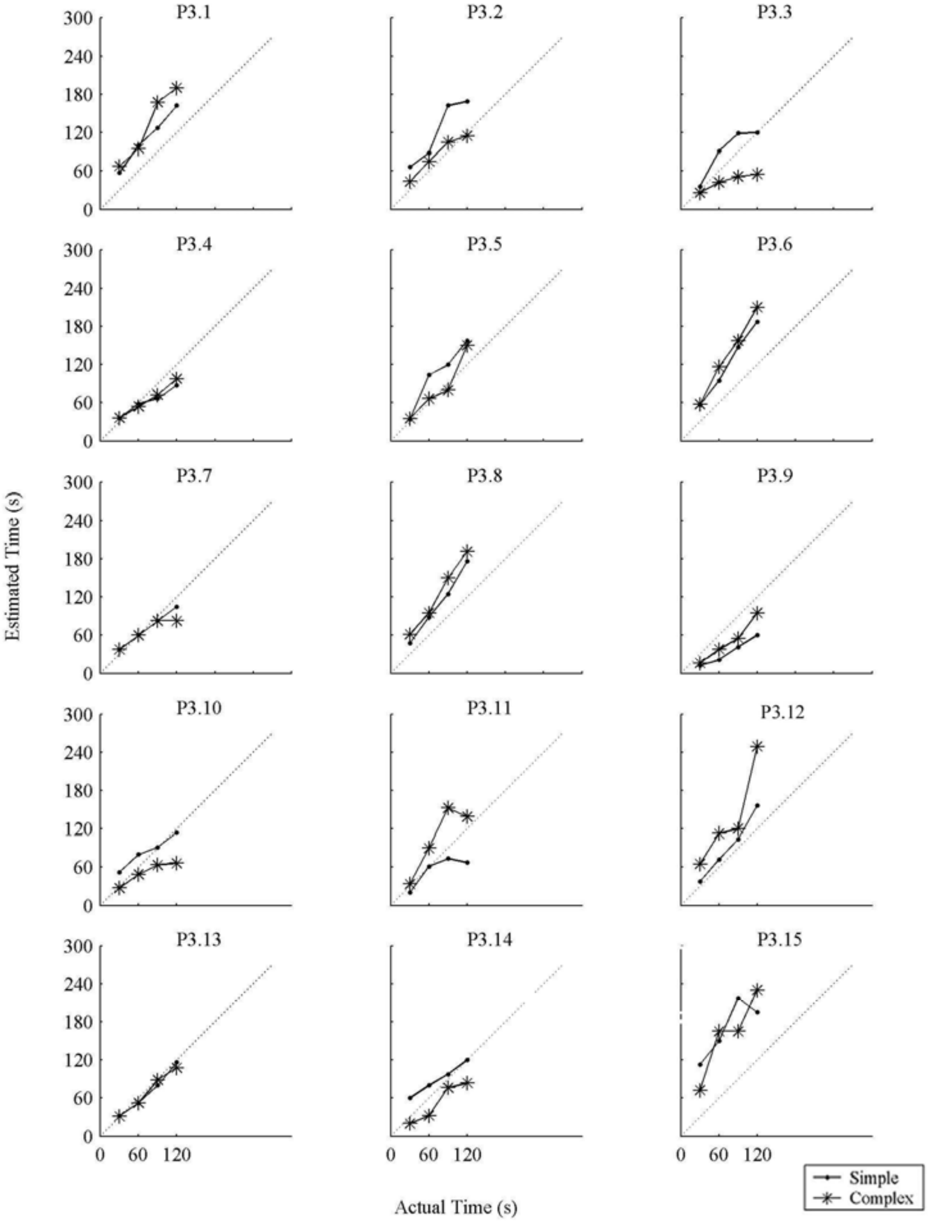

Figure 3.3. Scatterplot averages of participants estimates plotted against the actual times estimated for each condition.

actual times in both the simple and complex puzzle conditions.

Discussion

In this experiment, the disparity between the numbers of pieces in the puzzle in the two conditions was increased. There was, however, still no main effect of the number of puzzle pieces upon duration estimates. Thus, this attempt to manipulate task complexity by changing the number of pieces in the puzzle had no effect on estimates of duration.

The order of the intervals at which participants made their estimates was randomised to remove any possible confound of a fixed presentation order. Figure 3.3 showed that participants' estimates of duration varied, with some participants' (e.g., P3.11) estimates decreasing in both the simple and complex conditions at the 120-s interval and other participants (e.g., P3.6) consistently overestimating duration in both conditions. Comparisons of Figure 3.2 and Figure 2.2 show that participants in the present study estimated duration more accurately at all intervals than did the participants in Experiment 2, especially in the complex condition. It could be that randomising the times at which estimates were made resulted in this difference.

Previous research suggests that as a task gets more complex, time is estimated as passing faster than it is with less complex tasks (Allen, 1980; Axel, 1924; Dube & Schmitt, 1996; Loehlin, 1959). The results of the first three experiments here suggest that this is not the case for the task used here.

Researchers have also used methods other than the present one to measure participant's estimates of duration (Allan, 1979; Craik & Hay, 1999; Troutwine & O'Neill, 1981). One method, the production method (Allan, 1979) is where participants are told beforehand how long they are to work on the task. Participants then begin the task and terminate the trial when they think the specified time period has elapsed. The production method has provided reliable estimate measures (Craik & Hay, 1999). Craik and Hay (1999) compared the methods of verbal estimation and production, and concluded that there were no differences in the results between the two methods. The next experiment used the production and the estimation methods and compared the results from each method to see if Craik and Hay's (1999) results were reproduced using a jigsaw task.

EXPERIMENT 4

In the first three experiments the estimation method was used, where participants were asked to estimate the time that had passed by writing down their estimates. Another reliable method that has been used for gaining such estimates is the production method (Allan, 1979; Craik & Hay, 1999). In the production method participants are asked to indicate when they think a particular time has passed. Craik and Hay (1999) compared the two methods to test whether there were any differences in the results. They suggested that both methods should give similar results and found that this was so. This next experiment used both estimation methods with the current procedure. The aim was to compare the results from the verbal estimation method with those from the production method to see if Craik and Hay's results held for the present procedure.

Method

Participants

Sixteen participants were recruited as in Experiment 1. They are referred to as P4.1 to P4.16.

Apparatus

The apparatus was the same as that used in Experiment 1.

Procedure

The procedure was the same as that used in Experiment 3, except for one difference. Participants had to 'produce' or work on a puzzle for a specified set period, as well as make estimates of duration as they did in Experiment 3. Half of the participants did the production condition first and of these participants, half of them did the simple puzzle first and half did the complex puzzle first. The other half of the participants did the estimation condition first and of these participants, half of them did the simple puzzle first and half did the complex puzzle first. The specified durations for the production conditions were 30 s, 60 s, 90 s and 120 s, and the order in which they were presented was randomised. Like the earlier experiments, the Experimenter escorted participants into the computer laboratory. Each participant sat down at a computer and was asked to read the sheet of instructions. The instructions were as follows:

Introduction:

This experiment involves working with jigsaw puzzles where you move pieces around to complete a picture. You will be required to do a puzzle and to estimate how long you think it is taken you to do the puzzle. You will also be required to do a puzzle for a set period (this is known as 'production'). Please read the steps below to familiarise yourself with the experimental procedure.

Step 1: In each half of the experiment, a puzzle will be displayed on the computer screen. Each of these squares is part of a picture you will see in the top left hand corner of the computer screen when you move the pointer over the preview button directly to the right of the target picture. Your task is to use the mouse to move the pointer over a square and depress the left mouse button to drag that square to a new location. You can repeat this process as you work on the puzzle.

Step 2: As you work on the puzzle, a box will appear every now and again in the centre of the computer screen asking you to estimate how long you think you have currently spent doing the puzzle. You may write your estimate in terms of minutes or seconds or both on the estimation sheet provided. As you progress through the experiment a box will also appear asking you to **'produce'** or do the puzzle for a set period.

If you have any questions please ask them now. You may start the experiment by using the mouse to move the pointer over the 'Start' button and depress the left mouse button to begin.

Once any questions were answered, the Experimenter asked the participant to remove their watch, if they were wearing one, and informed the participant that it would be returned at the end of the experiment. The Experimenter then told the participant that they could start when ready. The Experimenter remained in the room. No further communication between the Experimenter and the participant occurred until the end of the session. Once the participant had finished the experiment they were debriefed by the Experimenter as to the aim of the experiment.

Results

Figure 4.1 shows, for P4.1 to P4.8, the logarithms of the estimates over the actual times at which participants were required to make their estimates, for the production and estimation method, and corresponding complexity conditions, plotted against the successive

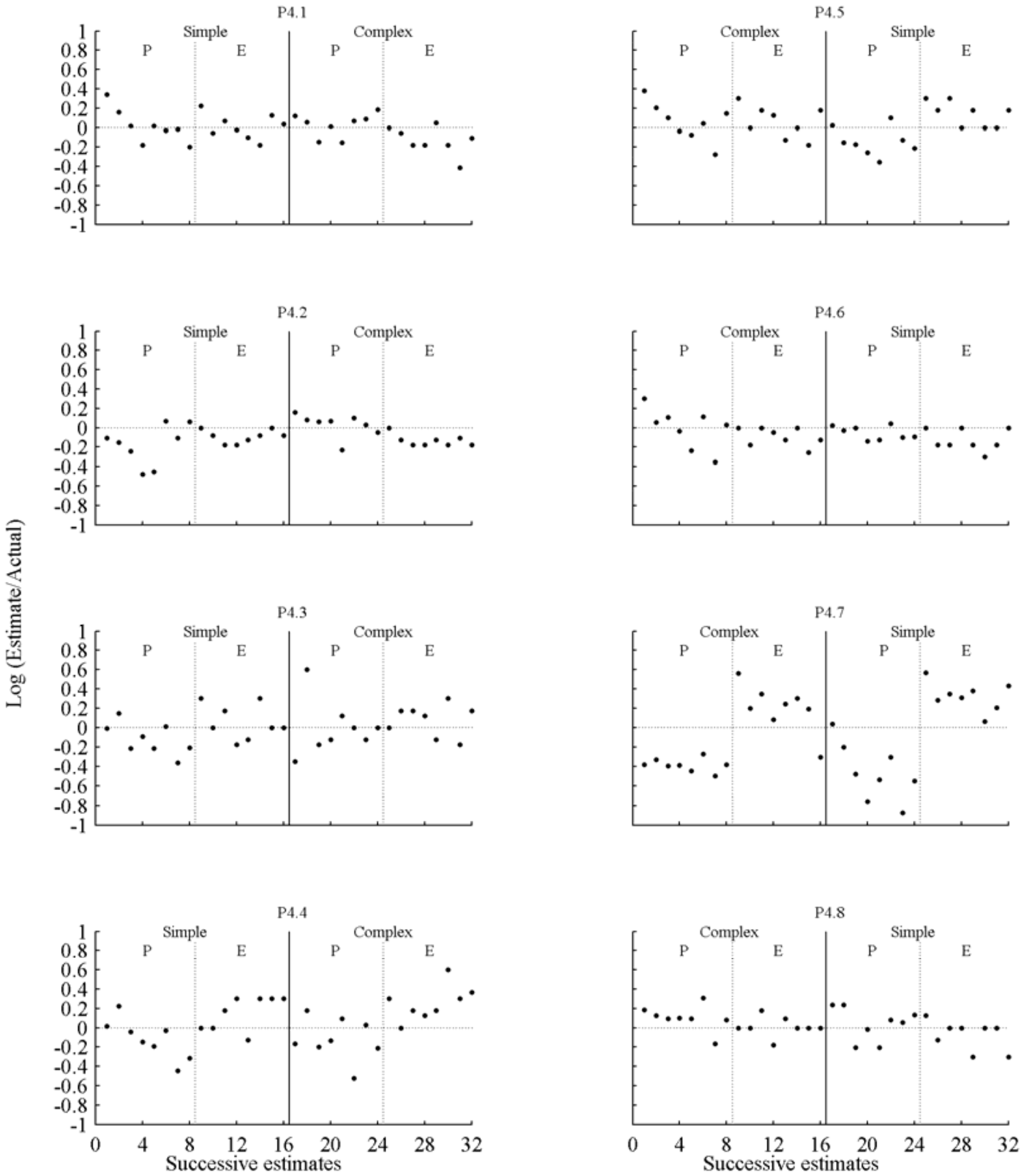

Figure 4.1. Logarithms of the estimates over the actual times, for the production and estimation methods, and corresponding complexity conditions, plotted against the successive number of estimates made in the session, for P4.1 to P4.8.
P = Production: E = Estimation.

number of estimates made throughout the session. As in previous experiments these graphs show the error in successive estimations over the course of the session but do not show which time was being estimated. P4.1 to P4.8 completed the method of production then the method of estimation, with the first four of these participants completing the simple puzzle then the complex puzzle and the last four completing the complex puzzle followed by the simple puzzle. The log ratios show that all of these participants both overestimated and underestimated duration over the conditions. For six participants (P4.1, P4.2, P4.3, P4.4, P4.5 and P4.6) there was a downward trend over the first few estimates of the session but apart from this, there were no clear systematic differences across all participants' data resulting from the number of puzzle pieces or the method of estimation visible in these data. For P4.7 the data show overestimation in the estimation conditions and underestimation in the production conditions; this is also visible to some degree for P4.4 and P4.5. For P4.1, P4.6 and P4.8, there is some sign of the ratios for the production method being higher than those from the estimation method.

Figure 4.2 shows the same data as Figure 4.1 for P4.9 to P4.16, who all completed the estimation method first in each condition. For these participants there are no trends at the start of the session and, again, there are no visible systematic differences across participants' data resulting from the number of puzzle pieces. P4.9, P4.10, P4.15 and P4.16 all showed some tendency to give higher error ratios in the estimation conditions than in the production conditions for both simple and complex puzzles, while P4.13 and P4.14 show the reverse (i.e., higher ratios with production than with estimation). Thus, visual analyses of these graphs suggest that, generally, the degree of overestimation and underestimation did not change systematically with either the method of estimation or puzzle complexity.

A repeated measures ANOVA was performed, with task complexity, method type and time (at which estimates were made) as within-subject variables and the order in which the task and method were presented as between-subject variables. The ANOVA compared the means of the logarithms of the estimates over the actual times at which participants were required to make their estimates, for both the simple and complex conditions, the method used, and for the actual times at which estimates were made. There was no main effect of complexity (i.e., number of pieces) (F (1, 12) = 3.927, $p > .05$) and the effect size was small (η = .247). There was also no main effect of the method used (i.e., estimation or production) (F (1, 12) = 2.973, $p > .05$) and the effect size was small (η = .199). There was no significant interaction between complexity and method used (F (1, 12) = 1.357, $p > .05$).

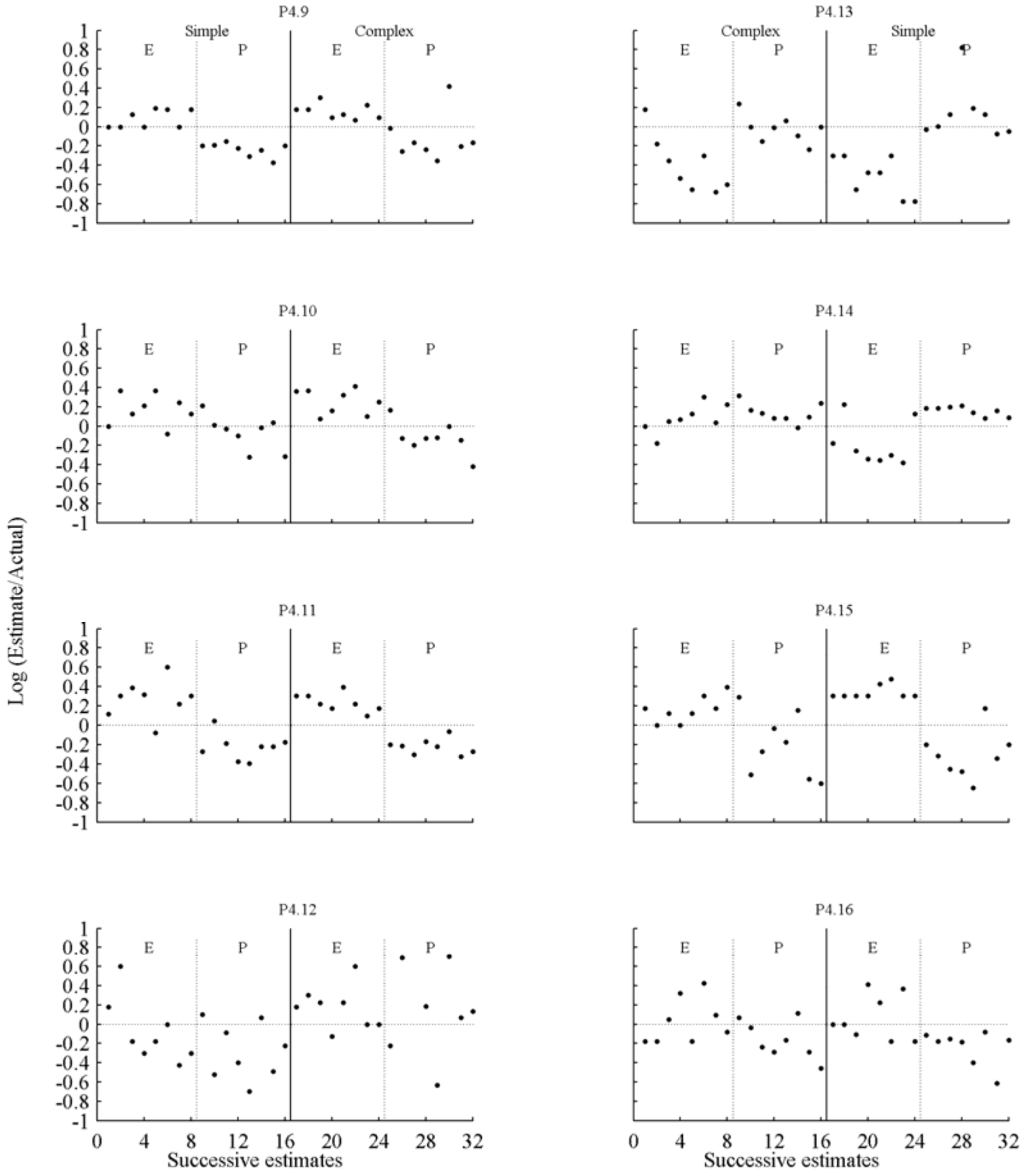

Figure 4.2. Logarithms of the estimates over the actual times, for the estimation and production methods, and corresponding complexity conditions, plotted against the successive number of estimates made in the session, for P4.9 to P4.16.
P = Production: E = Estimation.

There was a main effect of the times at which estimates were made (F (3, 36) = 16.984, p < .05) and the effect size was medium (η = .586). Pairwise comparisons showed that the log ratios from all intervals were significantly different to those from the other intervals, except the 90-s and 120-s intervals, which were not significantly different from each other (p >.05). There were no between-group effects of method presentation order (F (1, 12) = .000, p > .05) or of complexity presentation order (F (1, 12) = 1.392, p > .05). There was no interaction between method presentation order and complexity presentation order (F (1, 12) = .866, p > .05). The analyses also showed that there were no significant interactions between any combinations of complexity, method used and the times at which estimates were made, at the .05 alpha level.

The mean data from the simple and complex conditions are given in Figure 4.3. This shows the means of the logarithms of the estimates over the actual times estimated, together with the 95-percent confidence interval, from all data from the simple condition and all data from the complex condition. The mean data from the method of estimation are given in Figure 4.4. This shows the means of the logarithms of the estimates over the actual times estimated, together with the 95-percent confidence interval, from all data from each of the production and estimation conditions. These two figures show that the log ratios of the estimates made in the two complexity conditions were, on average, very similar to each other as were those from the two methods of estimation.

To investigate the effect of time to be estimated further, Figure 4.5 shows the logarithms of the estimates over the actual times estimated, together with the 95-percent confidence interval, for production and estimation, and corresponding complexity conditions averaged over all participants' data, plotted against the actual times. The squares indicate data from the production-simple condition; the asterisks indicate data from the production-complex condition; the circles indicate data from the estimation-simple condition, and the crosses indicate data from the estimation-complex condition. The mean ratios of the estimates of duration to the actual times decreased in all conditions as the intervals at which estimates were made increased. These differences over times were significant in the ANOVA reported above, except for between 90 s and 120 s. The mean estimates for the 30-s interval were generally overestimates and those for the 120-s interval were generally underestimates in all conditions. The mean ratios of the estimates to actual times from the production conditions were smaller than those during the estimation conditions for any particular time but, although consistent for these mean data, these

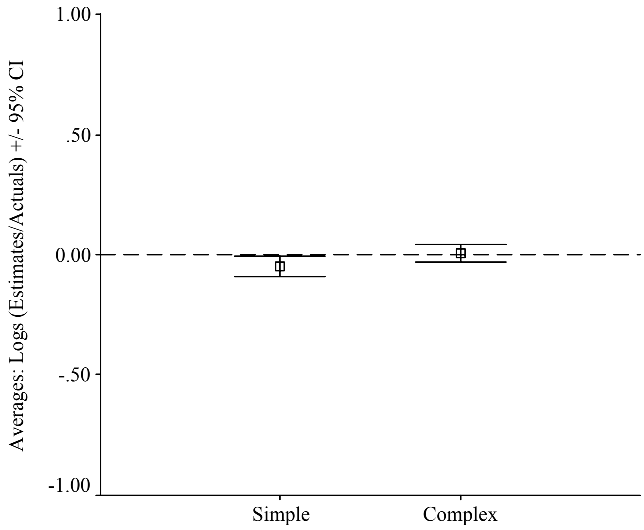

Figure 4.3. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, plotted against the simple and complex conditions.

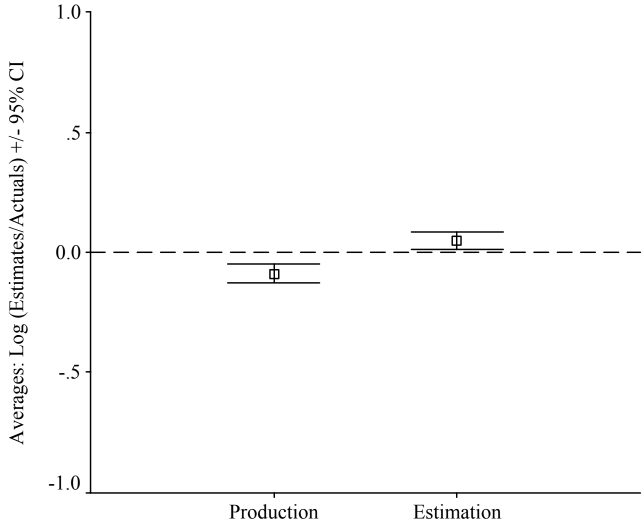

Figure 4.4. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, plotted against the production and estimation conditions.

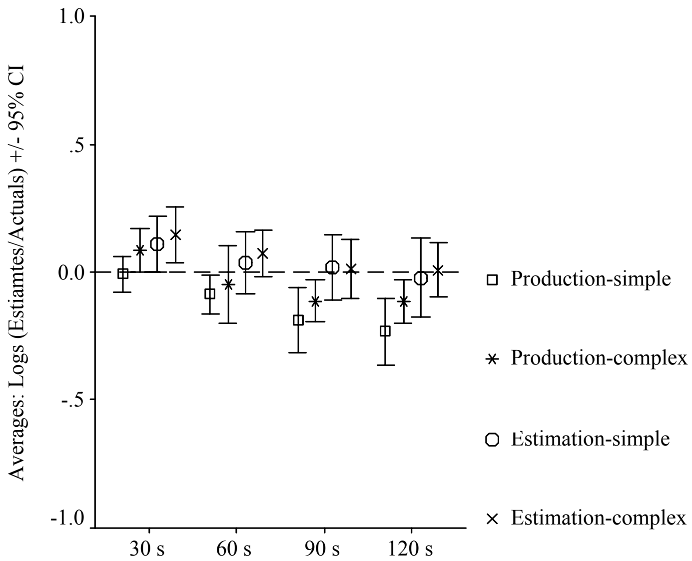

Figure 4.5. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, for both the method and complexity conditions, plotted against the times at which estimates were made.

differences were not significant in the ANOVA reported above.

To explore the individual data with regard to the interval being estimated further, Figure 4.6 shows a plot of the averages of each participant's estimates plotted against the actual times estimated, for both the simple and complex conditions, and the method used. The dotted lines show where the estimates would fall if they were completely accurate. Data points plotted above the line indicate overestimation and those below the line indicate underestimation. The dots indicate data from the production-simple condition; the asterisks indicate data from the production-complex condition; the circles indicate data from the estimation-simple condition, and the crosses indicate data from the estimation-complex condition. P4.1 through P4.8 completed the production condition first, whereas P4.9 through P4.16 completed the estimation condition first. P4.1 through P4.4 and P4.9 through P4.12 completed the simple condition first, whereas P4.5 through P4.8 and P4.13 through P4.16 completed the complex condition first.

The data shown in Figure 4.6 vary greatly between participants. P4.4, P4.7, P4.9, P4.10, P4.11 and P4.15 generally overestimated duration in the estimation and two complexity conditions at the 30-s, 60-s, 90-s and 120-s intervals. P4.4, P4.7, P4.9, P4.10, P4.11, P4.15 and P4.16 generally underestimated duration in the production and two complexity conditions at the 30-s, 60-s, 90-s and 120-s intervals. P4.2, P4.6 and P4.8 estimated duration relatively accurately in all conditions at all duration intervals. The data from Figure 4.6 indicate that there were no systematic differences in the estimates across participants for complexity, estimation method or interval being estimated. The data do not show any consistent trend in the estimation of duration for any condition or for the times at which estimates were made.

Discussion

In this experiment, the estimation method was compared with the production method. There were no significant differences resulting from the method of estimation. The graphical analysis supports this, in that there were no systematic effects of method or complexity. That there were no differences found between the estimation methods is consistent with results from previous research where different methods were directly compared (Allan, 1979; Craik & Hay, 1999). In this experiment and in Experiment 3, the

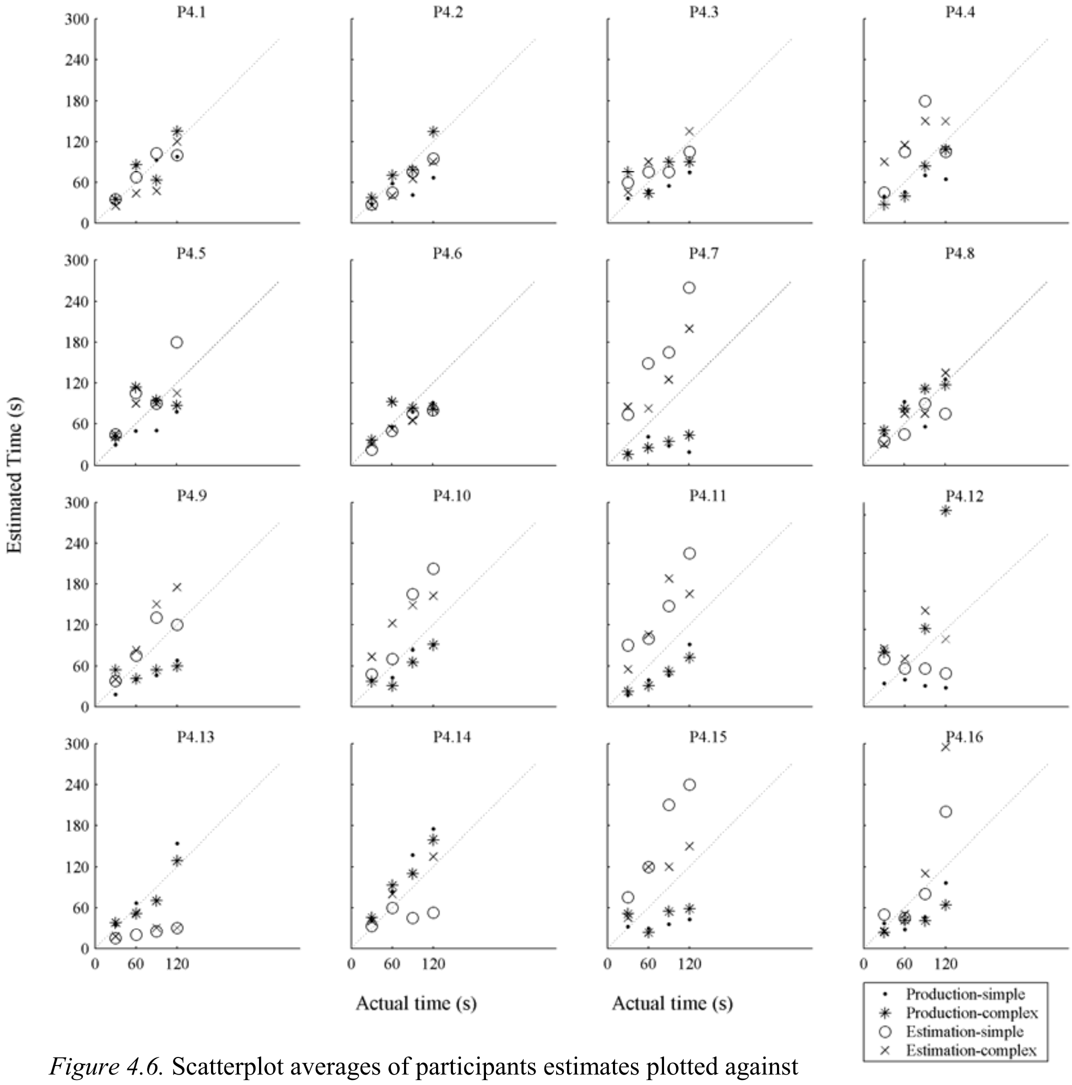

Figure 4.6. Scatterplot averages of participants estimates plotted against the actual times estimated for both the method and complexity conditions.

times at which estimates were made were randomised so as to avoid any possible confound of a fixed presentation order. In this experiment, there was an effect of the times at which estimates were made on participants' estimates of duration, except at the 90-s and 120-s intervals. In Experiment 3 there was an effect of the actual times but only at the 30-s interval. Thus, when estimates are made after a longer duration period has passed, it appears that participants have a tendency towards underestimating duration, whereas at shorter durations, they tend to overestimate duration (see Figures 3.2 and 4.5).

The results of the current experiment and those from the first three experiments, suggests that varying the number of puzzle pieces did not affect participant's estimates of duration, unlike the results previous researchers have reported for other tasks (Allen, 1980; Axel, 1924; Dube & Schmitt, 1996; Loehlin, 1959). These researchers varied task complexity extensively along different dimensions in their experiments, arguing that time was perceived to go faster as a function of the task being more 'complex', and that time was perceived to go slower as a function of the task being less 'complex'. It might be expected that the results from varying task complexity by varying the tasks (e.g., anagrams and mathematical problems) would be comparable to those tasks varying complexity on one dimension (in this case number of jigsaw puzzle pieces). This was not the case.

It may be possible, however, that no comparison can be made between tasks that use different types of stimuli (e.g., anagrams and jigsaw puzzles) because the tasks are very different. Further investigation is required to, as it was stated at the beginning of this thesis, 'show how task complexity can be used as an explanation for why estimations of duration differ'. A comparison could be made with a task that is similar to jigsaw and varies on one dimension only. The results of such a comparison should provide a basis for developing a procedure to further examine the human estimation of duration. The next series of experiments partially replicates the methodology of two earlier task complexity studies where the different complexity tasks involved the same stimuli, as in the jigsaw here, and where complexity was varied by varying the actual task required. The first of these two experiments is a study by Allen (1980), where task complexity was manipulated by getting participants to sort playing cards into one stack (face up), two stacks according to colour and four stacks according to suit for three different durations. Sorting cards into four stacks was the most complex of the sorting tasks. Participants then made estimates about how long they thought they had been sorting cards. This task has been used by other researchers as a simple and effective way of manipulating time judgements (Hicks, Miller, Gaes & Bierman, 1977; Hicks, Miller & Kinsbourne, 1976).

The card sorting task was thought to be similar to jigsaw because the task was visual, in that each playing card showed a picture (the royal cards) or variations of pictures (the house cards). Secondly, the number of cards able to be shown (similar to the number of pieces visible) was easily manipulated, in that one, two or four cards were turned over at any one time. Thirdly, the task was one dimensional (i.e., only cards were used). Finally, the card sorting task was a within-subjects design, like jigsaw. This task was also easy to reproduce, given experimental time constraints. A fuller description of the procedure and methodology is given in Experiment 5.

EXPERIMENT 5

In this experiment, a previous task complexity study (Allen, 1980) was partially replicated as a basis for developing a procedure to investigate time estimation further. Allen (1980) investigated the effect of task complexity (in this case different card sorting tasks) and the effect of situation (one designed to be perceived as pleasant and another designed to be perceived as unpleasant) upon 24 participants' estimates of duration. Allen (1980) proposed a cognitive argument of 'task-relevant' processing, where a person actively 'processes' stimuli, which in turn affects their estimates of duration. For example, a person may translate stimuli into binary choices, which has the effect, according to Allen (1980), of decreasing estimates of duration or making time appear to go faster. The card sorting task in Allen's (1980) study required participants to sort playing cards into one stack (face up), two stacks according to colour and four stacks according to suit. Sorting cards into four stacks was the most complex task, because Allen (1980) claimed that there were more stimuli (increased amounts of information) to 'process'. Thus, Allen (1980) suggested that internal task-relevant processing may affect estimates of duration contingent upon the complexity of a task.

Allen (1980) used two groups of participants (the between-subjects component), three task complexity conditions, one control condition, and three different durations (the within-subjects component). Participants were tested individually in a laboratory and were supervised by an undergraduate student, who was also a confederate in the study. The confederate told one group that another experiment was being conducted where lengthy columns of numbers were being added up on paper and then torn up. The other group was told that in another experiment, participants were rating pictures of nudes. This information was fictitious and constituted the situational component of the study. Once participants were given this information, the procedure was the same from then on for both groups. Allen (1980) predicted that the card-sorting task would be perceived as being boring for the group told about the nude picture-rating task and interesting for the group told about the number task.

Participants were then asked by the Experimenter to sort playing cards and were told to estimate time intervals between when the Experimenter instructed them to 'start' and then 'stop' timing. The three duration intervals used were 13 s, 22 s and 37 s. During the interval that they were required to time, participants sorted the playing cards into stacks (as described above). In the control condition, participants did not sort cards but just estimated duration. At the end of the experiment, after all the card sorting had been completed, using a 1-to-10 scale, participants rated their experience of the experiment, where the digit '1' signified an extremely boring experience and the digit '10' signified an extremely interesting experience.

Allen (1980) found that task complexity (i.e., card sorting) affected participants estimates of duration. Estimates of duration were longest in the control condition and shortest in the most complex card-sorting (i.e., four-stack) condition. The estimate averages (over all three duration intervals) for the 1-stack, 2-stack, 4-stack and control conditions were: 25.15 s, 25.56 s, 22.39 s and 27.11 s respectively. The number of cards sorted in each condition differed significantly, with fewer cards being sorted in the four-stack condition (i.e., the information being processed affected the number of cards sorted). There were also significant differences in estimates made at each of the three duration intervals. The estimate averages for the 13 s, 22 s and 37 s conditions were: 15.28 s, 24.28 s and 35.59 s respectively. The two groups did not differ significantly in how they estimated time to pass but did differ (as predicted) in how they rated their experiences (i.e., the group told about the nude picture-rating task thought the card-sorting task was boring).

The card sorting task has also been used by other researchers as a simple and effective way of manipulating time judgements (Hicks et al., 1977; Hicks et al., 1976). Hicks et al. (1976) investigated the effect of varying information processed (as outlined above in Allen's (1980) study) by participants during an interval using two timing paradigms. Participants were required to sort playing cards into a single stack, face up; two stacks according to colour and four stacks according to suit. Cards were sorted for a period of 42 s. The Experimenter instructed participants when to begin sorting cards, when to stop sorting them and when to make their estimate. Two types of estimates were made. The first was prospective, where the participants were told before starting the task that they would have to make an estimate of how long they thought they had been sorting cards. The second was retrospective, where participants were told to estimate time once the 42 s card-sorting period had elapsed. Hicks et al. (1976) found that prospective estimates decreased as more cards were required to be sorted (i.e., four stacks according to suit). The estimate averages for the 1-stack, 2-stack and 4-stack conditions were: 52.92 s, 42.83 s and 31.00 s respectively. Retrospective estimates were not linearly related to cards sorted into stacks (i.e., estimates did not decrease as the number of cards required to be sorted increased).

Hicks et al. (1977) investigated the effects of concurrent tasks upon participant's estimates of duration in four experiments. In the first experiment, the concurrent task was a card sorting task, which required participants to sort cards as well as make a judgement about how much time had passed whilst cards were being sorted. Cards were sorted into a single stack, face up; two stacks according to colour and four stacks according to suit. There was also a control condition where no cards were sorted but where an estimate was still made. There were three durations: 8 s, 13 s and 22 s. The prospective estimate paradigm was used and the Experimenter instructed participants when to start and stop sorting cards and when to make their estimates. Hicks et al. (1977) found that estimates decreased as more cards were sorted (i.e., 'processed'). Estimates were largest in the control condition compared to estimates made in any of the three card sorting conditions. The estimate averages for the 1-stack, 2-stack, 4-stack and control conditions were: 19.54 s, 16.49 s, 16.39 s and 20.91 s respectively.

The three studies described above all used card sorting tasks to influence how participants estimated duration. This experiment used the within-subjects component of Allen's (1980) study (i.e., card sorting at three intervals) to investigate how estimates of duration might be affected by using the card sorting task from Allen's (1980) study as a way of manipulating task complexity. Allen's (1980) study was selected for three reasons. Firstly, because the times at which estimates were made (i.e., the card sorting intervals) varied, just like the times at which estimates were made in the previous three experiments in this thesis. In the study by Hicks et al. (1976) only one interval was used. Secondly, the effect size in Allen's (1980) study of card sorting on duration estimates was medium. This was calculated from *F* and the degrees of freedom:

$$R^2 = \frac{(F)(df_{Between})}{(F)(df_{Between}) + df_{Within}}$$

Finally, Allen's (1980) study, used the prospective method of estimation, which had been used in the studies by Hicks et al. (1976) and Hicks et al. (1977), where it had been found that estimates decreased as more cards were sorted. Thus, the prospective method of estimation appeared to be a reliable way to measure estimates when using a card sorting task. The between-subject situational group comparison from Allen's (1980) study was not replicated because the effects of social situations were not being studied here.

Method

Participants

Nine participants were recruited as in Experiment 1. They are referred to as P5.1 to P5.9.

Apparatus

The experiment was conducted in a room, 3 m x 2.1 m, lit by 2 fluorescent tubes. Two decks of Realm Playing cards were used to manipulate the experimental events. One recording sheet was used by the Experimenter to record the participant's estimates.

Procedure

At the start of the session, the Experimenter escorted one participant into the laboratory. The participant sat down at a desk and was asked to read the sheet of instructions. The instructions were as follows:

Introduction:

This experiment involves working with playing cards. You will be required, at certain times, to sort the cards into piles and to estimate how long you thought it took you to sort the cards. At other times you will not be required to sort the cards into piles, but just estimate the time that has passed. Please remove your watch (if you are wearing one) and give it to the Experimenter. Your watch will be returned after the experiment. Do not attempt to count or mark time in any way during the experiment. Please read the steps below to familiarise yourself with the experimental procedure.

Step 1: In front of you on the desk are two packs of playing cards shuffled together into one pile, with Jokers removed. During the trials when you are required to sort the playing cards, you will sort them into either a single stack, face up; into two stacks according to colour, or into four stacks according to suit. The Experimenter will tell you before you start whether you will sort the cards into a single stack, two stacks or four stacks. You will begin sorting the cards when the Experimenter says, "Start" and stop sorting the cards when the Experimenter says "Stop". Once you have stopped sorting the cards, tell the Experimenter how long you thought you were sorting them. You may estimate time in terms of minutes, seconds or both. The Experimenter will record your estimate and then reshuffle the cards in preparation for another trial.

Step 2: At other times in the experiment you will not be required to sort the cards. The Experimenter will tell you when this will happen. On these trials you will be required to estimate time only, remembering not to count or mark time in any way. The Experimenter will say, "Start" and you will begin to estimate time passing. When the Experimenter says "Stop" you will stop estimating time. You will then tell the Experimenter how long you thought the time was during that interval, either in minutes, seconds or both. After the Experimenter has recorded your estimate, another trial will begin. The Experimenter will tell you what the trial will be before you begin, i.e., another card sorting trial or an estimate only trial.

Once any questions were answered the Experimenter asked the participant to remove their watch, if they were wearing one, and informed the participant that it would be returned at the end of the experiment. The experiment then commenced.

Each experimental session consisted of twelve trials. Each trial involved a combination of one of three durations and either one of three card sorting tasks (at three levels of complexity) or a period of waiting (control condition). Each interval/task combination occurred once per participant. The three card sorting tasks were: sorting cards into a single stack face up (the lowest level of complexity); sorting cards into two stacks according to colour (the medium level of complexity), and sorting the cards into four stacks according to suit (the highest level of complexity). In the control trials, no card sorting was required. Each trial was 13-s, 22-s or 37-s long.

The Experimenter timed each trial with a stopwatch and told the participant when to start and when to stop each trial and which task they were to do. He also asked participants for their time estimate at the end of each trial and recorded these. The twelve task/interval combinations were ordered according to a randomly determined sequence and this same sequence was used for all participants. Once the twelve trials had been presented the participants were thanked by the Experimenter for participating and were debriefed as to the aim of the experiment.

Results

Figure 5.1 shows the logarithms of the estimates over the actual times at which participants were required to make their estimates, for the card sorting conditions, plotted against the successive number of estimates made in the session. P5.2, P5.5, P5.7 and P5.8 generally underestimated duration in all conditions. P5.1 and P5.4 generally overestimated duration in all conditions. P5.3, P5.6 and P5.9 underestimated and overestimated duration throughout the session.

A two-way repeated measures ANOVA was performed, with cards sorted and the times at which estimates were made, as within-subject variables. The ANOVA compared the means of the logarithms of the estimates over the actual times at which participants were required to make their estimates, for the cards sorted and for the actual times at which

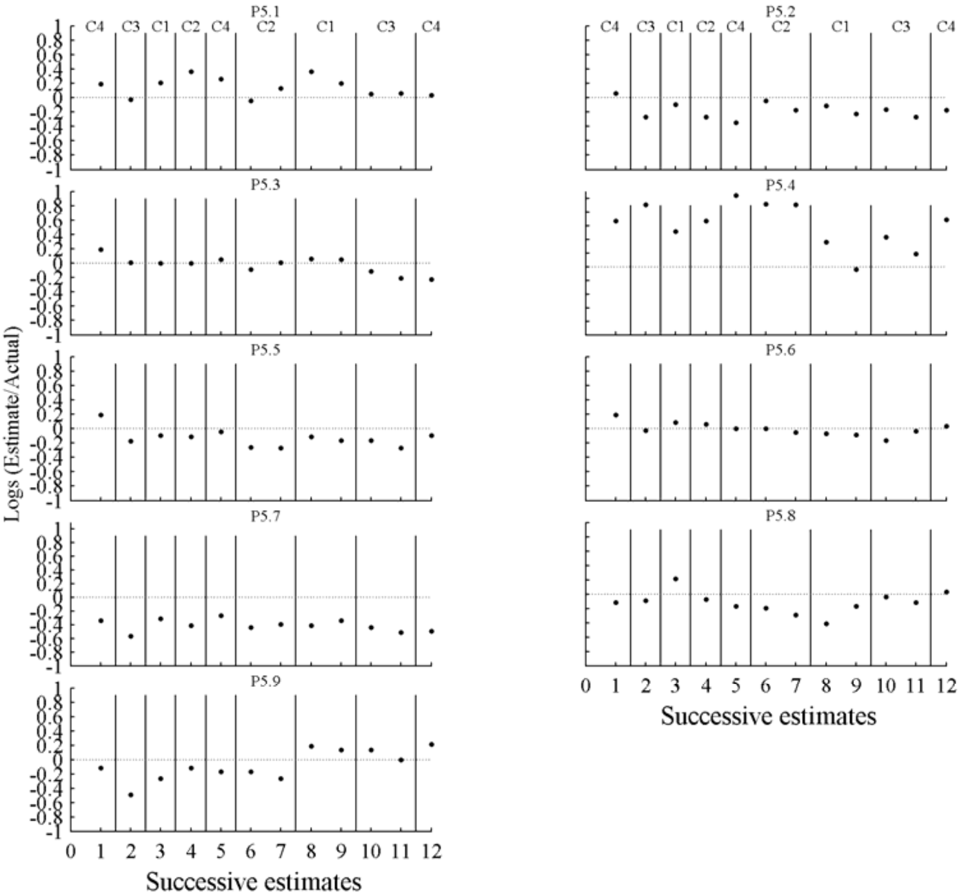

Figure 5.1. Logarithms of the estimates over the actual times for the card sorting conditions, plotted against the successive number of estimates made in the session. C1: Control; C2: 1 Stack; C3: 2 Stacks; C4: 4 Stacks.

estimates were made. It was found that there was no main effect of manipulating the number of cards sorted (F (3, 24) = 2.573, p > .05) or of trial duration (F (2, 16) = 0.162, p > .05) on estimates of duration. The effect size for cards sorted was small (η = .020) and effect size for trial duration was also small (η = .243). There was no interaction between cards sorted and trial duration (F (6, 48) = 0.798, p > .05) and the effect size was small (η = .091).

This lack of effect can be illustrated further. Figure 5.2 shows the means of the logarithms of the estimates over the actual times estimated, together with the 95-percent confidence interval, from all data from the card sorting and control conditions. The estimates from the three card sorting conditions were very similar to each other and to the estimates made during the control condition. The estimate averages for the 1-stack, 2-stack, 4-stack and control conditions were, 36.67 s, 29.85 s, 38.11 s and 27.30 s respectively.

Figure 5.3 shows the means of the logarithms of the estimates over the actual times estimated, together with the 95-percent confidence interval, from all data from the three trial durations. The log ratios of the estimates to the actual times from the three trial durations are very similar.

Discussion

This experiment partially replicated the procedure of a previous task complexity study (Allen, 1980). However, although the procedure was replicated, the results were not. Allen (1980) found that participants consistently estimated duration as passing faster with the more complex card sorting tasks. Here, there was no effect of card sorting (i.e., task complexity) on participants' estimates of duration.

The results of this experiment did not support the idea that the number of cards sorted in specified piles would affect estimates of duration as there were no systematic effects, as shown in Figure 5.1. Similarly, the data from Figures 5.2 and 5.3 do not show any systematic effects of estimates of duration. The estimate averages for participants in this experiment were larger in the card sorting conditions than those in Allen's (1980) study (although the estimate averages in the control condition were similar). The estimate averages for each of the three time intervals were larger than those found in Allen's (1980)

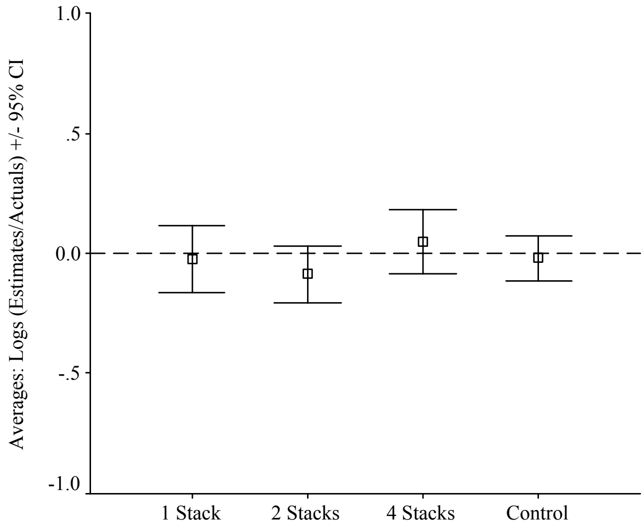

Figure 5.2. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, plotted against the card sorting and control conditions.

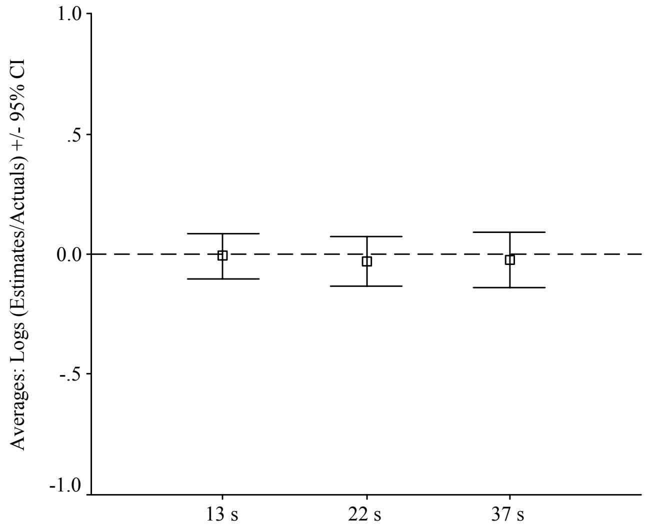

Figure 5.3. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, plotted against the three trial durations.

study at the 22-s and 37-s intervals, but were similar at the 13-s interval.

The estimate averages for the 13 s, 22 s and 37 s conditions were 15.94 s, 30.39 s and 52.61s respectively. The estimate averages for the three trial durations (see Figure 5.3) when compared to the estimate averages for the four trial durations in Experiment 4 (see Figure 4.5) show for the card sorting task, that participants did not tend to increasingly underestimate duration as the times at which estimates were made increased, as was the case for the jigsaw puzzle task.

The task complexity component of Allen's (1980) study was precisely replicated in this experiment. However, the results from this experiment do not support the claim that estimates decrease or increase as predicted in relation to the different levels of task complexity, when the task requires sorting cards into piles. Thus, it is not clear why Allen's (1980) task complexity results were not replicated here.

Allen (1980) suggested that having increased amounts of information to process results in estimations of time going faster. If this argument is correct, then in the earlier four jigsaw experiments it would have been expected that time would reliably be estimated as going faster in the complex conditions (i.e., where there were more puzzle pieces and therefore, more information to 'process'). However, this was not the case. Similarly, in this experiment in the more complex card sorting task conditions, time was not estimated as going faster than in the less complex card sorting conditions. However, in the studies by Allen (1980), Hicks et al. (1976) and Hicks et al. (1977) estimates decreased as more cards were required to be sorted. The inconsistency in the results of this experiment and of those in the previous earlier experimental series of this thesis, suggests the results from the studies by Allen (1980), Hicks et al. (1976) and Hicks et al. (1977) may not be reliable. In all of these three studies, and in the current experiment, the methodology used was very similar (i.e., the prospective method of estimation was used and cards were sorted into the same stacks). However, despite these methodological similarities, the results of this experiment differed to those from the three card-sorting studies.

Given the failure to replicate the card sorting task findings, the next experiment was the second in the series that partially replicated a task complexity study in a further attempt to develop a procedure for investigating how the complexity of a task affects people's estimates of time. A study by Hogan (1975) was selected from the task complexity literature. The stimuli used in this study (e.g., line drawings) were easily replicable and the complexity of the task was clearly defined, and therefore, allowed for ease of manipulation. A fuller description of the procedure and methodology is given in Experiment 6.

EXPERIMENT 6

In Experiment 5, the procedure from a task complexity study (Allen, 1980) was partially replicated as a basis for developing a procedure to investigate time estimation further. The results failed to replicate those of Allen (1980) and other similar studies (e.g., Hicks et al. (1976) and Hicks et al. (1977)) and it was unclear why this was so. Further investigation was required to explain these results but it was decided that a second attempt at finding a procedure be conducted instead. Thus, Experiment 6 involved partially replicating another task complexity study, this time one that used line drawings.

Two studies by Ornstein (1969) and Hogan (1975) investigated task complexity and time estimation using line drawings. Hogan (1975) investigated the effects of how experimental stimuli were qualitatively assessed by participants (i.e., what participants thought about the stimuli that were used) on time estimation. He used a between-subjects design, in which 137 participants were shown two sets of test stimuli; line drawings and colour slides of abstract paintings. Each trial consisted of either line drawings or paintings being presented. A standard drawing or painting was presented for 15 s immediately followed by a slide of a comparison drawing or painting also presented for 15 s. The comparison stimulus was randomly selected from a set of five comparison stimuli varying in complexity. The ten pairs of slides made up ten conditions, with each trial being experienced by different participants. During a trial and after the presentation of either the drawing or painting slide, participants circled a digit on a nine-point scale to indicate whether they thought the duration the comparison stimulus was presented for was shorter, equal to or longer than the duration the standard stimulus was presented for.
The qualitative aspect of the study required participants to answer three questions about whether they thought the comparison slide or the standard slide was more complex, more aesthetic and which slide they liked the best. These questions were asked after the completion of each trial. Hogan (1975) found that the durations of very simple and very complex stimuli were judged to be significantly longer than the durations for moderately complex stimuli. The mean time judgement scores, for the least-to-most complex stimuli were: 4.4, 4.3, 4.0, 4.3 and 4.5.

Hogan (1975) argued that overly simple and overly complex stimuli could not be cognitively processed, hence the durations were overestimated. Hogan argued that this was because overly complex stimuli, filled time (Fraisse, 1963), and overly simple stimuli, empty time (Fraisse, 1963), are perceptually and cognitively processed in the same way, resulting in overestimations of duration. Moderately complex stimuli are not perceived in the same way, as more stimulus information can be processed to give more accurate perceptions of time passing. This information is not available during empty intervals because of the lack of stimuli present and during filled intervals because the information is too stimulating and therefore cannot be processed. If it is assumed that viewing a simple stimulus is a simple task and viewing a more complex stimulus is a more complex task then these results do not agree with those from other task complexity researchers (e.g., Axel, 1924; Fraisse, 1963) where time is estimated as passing faster when tasks are more complex and slower when tasks are simpler. If Hogan's (1975) argument is correct, then it may be that the time spent doing very simple and very complex tasks would both be overestimated. Note, however, that Hogan used a between-subjects design.

Ornstein (1969) also tested the effects of varying the complexity of line drawings upon human's estimation of duration. Participants in Ornstein's (1969) study were shown a standard line drawing, followed by one of five complex drawings (see Figure 6.1). Both drawings were presented for 30 s and a within-subjects design was used. After the presentation of both drawings, participants were required to estimate how long the presentation of the complex drawing was in relation to the presentation of the standard drawing. Ornstein (1969) found that less complex line drawings were judged to be presented for a shorter duration than the standard drawing, and that more complex line drawings were not judged to be presented for a longer duration than the standard. Ornstein's results then agree with those of researchers such as Axel (1924) and Fraisse (1963).

Line drawings have produced interesting and contrary effects on time estimation. Given both studies reported at least some degree of effect, this next study involved the use of line drawings. The procedure was a partial replication of that used by Hogan (1975), using the stimuli designed by Ornstein (1969) and using a within-subjects design as used by Ornstein (1969). The qualitative aspect of Hogan's (1975) study was excluded as the relationship between time estimation and preferences for and aesthetic judgements of the environmental stimuli were not being investigated here. The study aimed to see if there were any consistent effects of these various line drawings on estimates of the relative presentation time on a standard and test stimulus.

Method

Participants

Fourteen participants were recruited as in Experiment 1. They are referred to as P6.1 to P6.14.

Apparatus

The experiment was conducted in a room, 7 m x 7.8 m, lit by 10 fluorescent tubes. Dell OptiPlex GX1 computers were used to control the experimental events.

Procedure

At the start of the session, the Experimenter escorted the participants into the laboratory. The participants sat down at a desk and were asked to read the sheet of instructions. The instructions were as follows:

Introduction:

> This experiment involves working with line drawings. You will be required to look at the line drawings that will be presented on the computer screen and to estimate how long you thought the drawings were presented for. Please remove your watch and give it to the Experimenter. It will be returned after the experiment. Do not attempt to count or mark time in any way during the experiment. Please read the steps below to familiarise yourself with the experimental procedure.

Step 1: To begin the experiment, push the space bar. Two sets of line drawings will be presented consecutively and this will constitute one trial. First, a standard line drawing will be presented, followed by a comparison line drawing. At the end of each trial you will write down on a recording sheet your estimate of whether you thought the comparison line drawing was presented for a shorter, equal or longer duration than the standard line drawing, using a 9-point scale. Write your name on the recording sheet before the experiment begins. Circle one number on the 9-point scale. The digits 1 to 4 indicate that the comparison line drawing is of a shorter duration than the standard line drawing; the digit 5 indicates that the comparison line drawing is of equal duration to the standard line drawing, and the digits 6 to 9 indicate that the comparison line drawing is of a longer than the standard line drawing.

Once any questions were answered the Experimenter asked the participant to remove their watch, if they were wearing one, and informed the participant that it would be returned at the end of the experiment. The Experimenter then told the participant they could start when ready. The Experimenter remained in the room. No further communication between the Experimenter and the participant occurred until the end of the session during debriefing.

There were five trials conducted in one experimental session. A standard line drawing, the same in each trial, was always presented first followed by one of five comparison line drawings, which were presented randomly. The same random order for the presentation of the comparison drawings was used for each participant. Both the standard and comparison line drawings were presented for a duration of 15 s, where the comparison was presented immediately after the standard. Figure 6.1 shows the line drawings selected from Ornstein's (1969) study that investigated differences in stimulus complexity using line figures. Complexity was varied in terms of the number of each drawings' interior angles; the more interior angles, the greater the complexity.

Participants estimated duration after each trial by circling one number on a 9-point scale, to indicate whether they thought the duration of the comparison line drawing was shorter than, a score ranging from one to four, equal to, a score of five, or longer than, a score ranging from six to nine, the standard line drawing. Once the estimate was made, another trial began by the participants pushing the space bar. When the experiment had finished, the participants were then thanked by the Experimenter for participating and debriefed as to the aim of the experiment.

Results

Figure 6.2 shows the relative duration ratings for the least to most complex stimuli presented to participants for each participant. For ease of presentation, and given that participants' duration ratings were variable, Table 6.1 groups them, showing the number of participants who rated the comparison stimulus, for each complexity level, as either longer, shorter than, or equal to, the standard stimulus. It can be seen from Table 6.1 that more participants rated the comparison stimulus as longer or shorter than the standard stimulus rather than, equal to it, when the comparison stimulus was least and most complex.

A Friedman test was conducted on the ratings of task complexity to assess whether or not there were any significant effects over the different complexity levels on the participants estimates. It was found that stimulus complexity did not influence the estimates of duration (χ^2 (df=4, N = 14) = 3.258, p > .05). Table 6.2 shows the mean rating scores as functions of stimulus complexity level. It can be seen that for the most complex

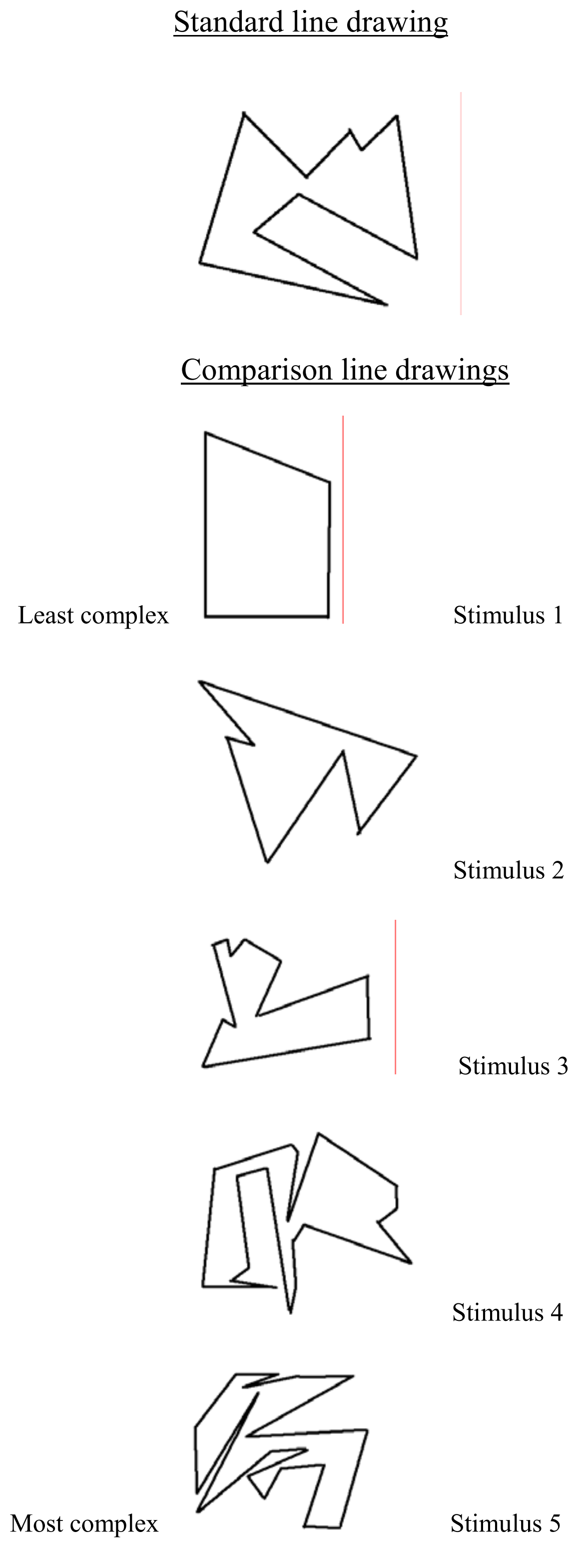

Figure 6.1. Standard and comparison line drawings (Ornstein, 1969).

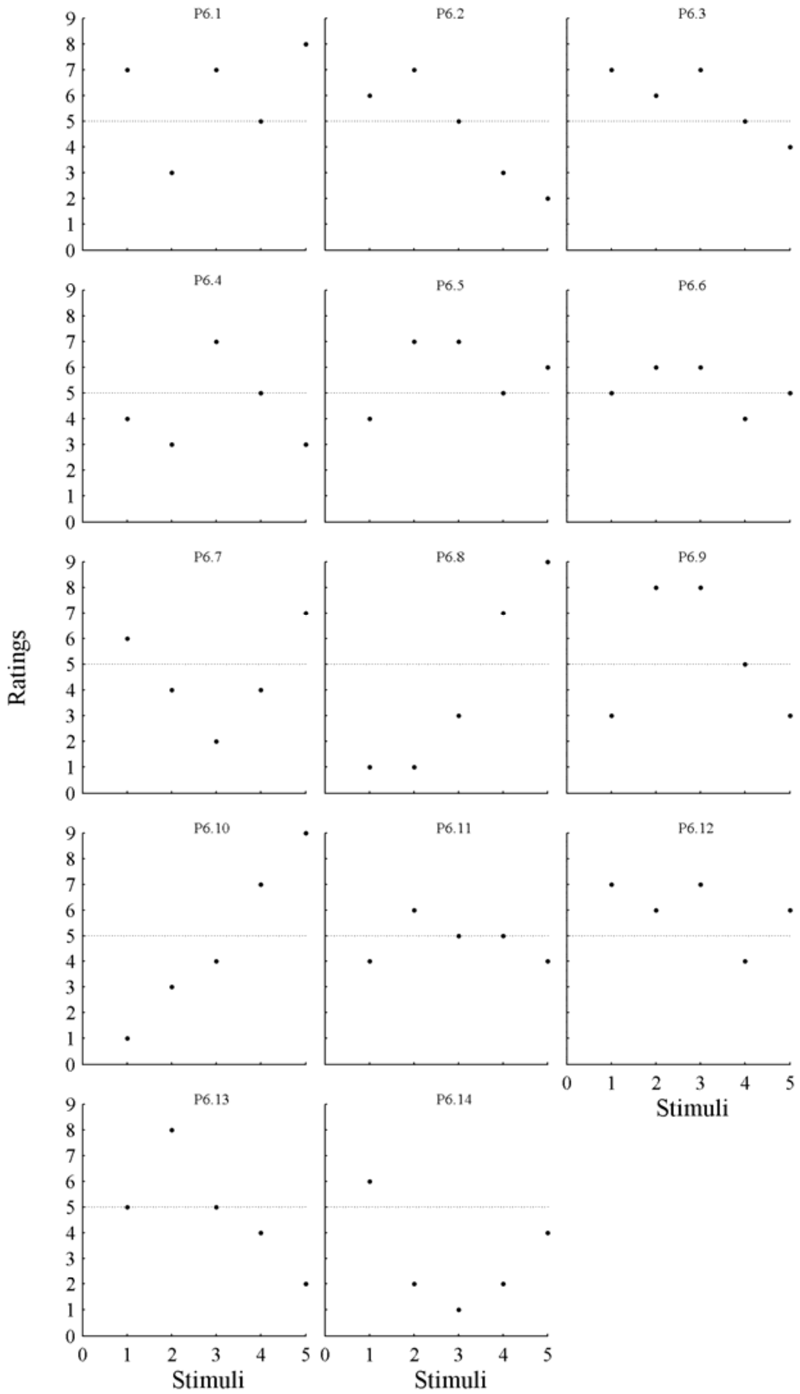

Figure 6.2. Participants ratings of durations plotted against the least to most complex comparison stimuli. 1 = least complex; 5 = most complex.

Table 6.1

<u>The rating of duration selected by each participant for each comparison stimuli.</u>

	Complexity Level				
	Least				Most
Duration Rating Comparison stimulus	1	2	3	4	5
Longer (than standard)	P6.1 P6.2 P6.3 P6.7 P6.12 P6.14	P6.2 P6.3 P6.5 P6.6 P6.9 P6.11 P6.12 P6.13	P6.1 P6.3 P6.4 P6.5 P6.6 P6.9 P6.12	P6.8 P6.10	P6.1 P6.5 P6.7 P6.8 P6.10 P6.12
Shorter (than standard)	P6.4 P6.5 P6.8 P6.9 P6.10 P6.11	P6.1 P6.4 P6.7 P6.8 P6.10 P6.14	P6.7 P6.8 P6.10 P6.14	P6.2 P6.6 P6.7 P6.12 P6.13 P6.14	P6.2 P6.3 P6.4 P6.9 P6.11 P6.13 P6.14
Equal (to standard)	P6.6 P6.13		P6.2 P6.11 P6.13	P6.1 P6.3 P6.4 P6.5 P6.9 P6.11	P6.6

Table 6.2

Mean rating scores as a function of stimulus complexity level.

Complexity level	Mean rating scores
Stimulus 1 (least complex)	4.7
Stimulus 2	5.0
Stimulus 3	5.3
Stimulus 4	4.6
Stimulus 5 (most complex)	5.1

stimulus, Stimulus 5, participants estimated the duration of this stimulus to be almost equal to that of the standard stimulus. The second to least complex stimulus, Stimulus 2, was judged exactly equal in duration to that of the standard stimulus. The durations for the least most complex stimulus, Stimulus 1, and the second to most complex stimulus, Stimulus 4, were judged slightly shorter than the duration of the standard stimulus. The duration for the third most complex stimulus, Stimulus 3, was judged to be longer than that of the standard stimulus.

Discussion

This study was a second attempt at trying to find a procedure to investigate time estimation further, given the lack of significant results from the first four task complexity experiments in this thesis and the previous partial replication (Experiment 5). The partial replication of Hogan's (1975) study required participants to estimate whether the presentation times of complex line drawings were longer than, shorter than or equal to, the presentation times of a standard line drawing. The present results did not replicate those of either Hogan (1975) or of Ornstein (1969). The relation between the estimates and complexity level varied unsystematically over participants.

The results from the all of the experiments so far in this study, Experiments 1 through 6, which included two partial replication studies, have not been able to show that task complexity, as varied here, affects estimates of duration as suggested by previous task complexity researchers (e.g., Axel, 1924; DeWolfe & Duncan, 1959; Fraisse, 1963; Smith, 1969; Wilsoncroft et al., 1978). The designs of the first four experiments were based around previous task complexity studies that reported effects of task complexity upon the human estimation of duration. Similarly, the two partial replications followed the procedures used in Hogan's (1975) and Allen's (1980) studies. Given the strong similarity between methodologies used in this thesis and those of previous task complexity studies, the question should be asked about the validity of those designs, given the non-significant results obtained from the first six experiments in this thesis. Where there were variations in procedures across studies, there were no obvious reasons why these should have affected the results. It seems that another approach is needed to explain how the tasks that people are engaged in affects their estimates of time passing.

INTERIM DISCUSSION

The first four experiments were designed to investigate how varying task complexity on one dimension would affect human estimates of duration. Complexity was manipulated by varying the number of pieces in a computer generated jigsaw puzzle. Over these experiments both the method of estimation and the method of production were used to measure participants' judgements of duration. The manipulations in the first four experiments did not significantly affect participants' estimates of duration.

Given these results, it was thought, at this stage, that what was needed was an attempt to see if manipulation of the variables other task complexity researchers had used would give control over estimates of duration. Consequently, the methodology of two different task complexity studies, those of Allen (1980) and Hogan (1975) were partially replicated. Both of these studies manipulated task complexity as well as testing other variables of interest (e.g., social perceptions). The partial replications consisted of manipulating only the task complexity aspect of each of these studies. The results of the replications showed that there was no effect of task complexity upon participants' estimates of duration, whereas in the original studies, Allen (1980) and Hogan (1975) found an effect of task complexity.

Despite several attempts at conducting experiments to assess how task complexity influences a person's perception of time passing, the findings from this series of experiments brings into question the validity of the task complexity designs used in this thesis, as these findings do not support results as previously reported by task complexity researchers. Generally, the argument is that if a task is more complex, time is perceived to go faster, and if a task is less complex, time is perceived to go slower (Allen, 1980; Axel, 1924; Craik & Hay, 1999; DeWolfe & Duncan, 1959; Dube & Schmitt, 1996; Fraisse, 1964; Gray et al. 1975; Gulliksen, 1927; Hogan, 1975; Juhnke & Scott, 1988; Loehlin, 1959; Sawyer, Meyers & Huser, 1994; Smith, 1969; Watt, 1991; Zakay, Nitzan & Glicksohn, 1983). Within task complexity studies, however, there is much variability in design, such as varying task complexity on different dimensions, rather than on just one dimension. For example, Loehlin (1959) compared estimates of duration from participants who were involved in many different tasks, such as counting 'the's' and solving anagrams. The discrepancy in results from this series of experiments and the task complexity literature suggests that more research is needed into finding out how task complexity affects human's estimates of duration. Maybe this should not be surprising, given the great range of methodologies used in task complexity research (e.g., dimensional and task variations). A theoretical approach is needed, one that might explain and clarify what task complexity is and how the complexity of a task influences a human's perception of time passing.

The Behavioral Theory of Timing

In basic animal research on the perception of duration, the findings are less ambiguous than those from the human literature on task complexity. Results from basic behavioural animal research on timing support a theoretical approach known as the behavioral theory of timing (Killeen & Fetterman, 1988, 1993). Inherent to this theory, is the idea that behaviour is determined by consequences, which are perceived by the organism as being either positive (i.e., reinforcing) or negative (i.e., punishing). The behavioral theory of timing (BeT) suggests that the rate of reinforcement or how often reinforcers are received by an organism, drives the speed of an internal pacemaker, a hypothesized regulator within the organism, which governs an organism's perception of time passing (Killeen & Fetterman, 1988, 1993). An organism emits responses called adjunctive behaviours (Killeen & Fetterman, 1988, 1993). These behaviours are states that correspond to each class of adjunctive responses. An organism learns to associate certain responses with reinforcement in the context of the behaviours associated with that state. The pacemaker emits pulses that move the organism into a state that it has learned to associate with a cue for making a response. For example, a pigeon may make a 'short' response, if at the time of response requirement, it was engaged in behaviour (e.g., preening) it had learnt to associate with the short-duration stimulus. Contingent upon making the response, the organism moves from one state to the next as a function of the pulses emitted by the pacemaker. Changes in pacemaker speed are assumed to be mediated by changes in the arousal level of the organism, which is driven by the rate of reinforcement.

Research into BeT has shown that humans' and pigeons' estimates of duration vary as a function of specifically manipulating the reinforcement rate (Bizo & White, 1995a; 1994a; 1994b; Fetterman & Killeen, 1990, 1991; Morgan, Killeen & Fetterman, 1993; Wearden, Philpott & Win, 1999). Bizo and Whites' (1995a; 1994a; 1994b) studies used a two-alternative free-operant psychophysical procedure. Pigeons responded on either the left or the right key in a 50-s trial. During the first 25 s of the trial, responses to the left key were reinforced and during the last 25 s of the trial, responses to the right key were reinforced. There were forty-eight trials, each separated by an inter-trial interval. Bizo and White (1995a) investigated whether differential rates of reinforcement affect changes in the pacemaker period. The manipulation of the differential rate of reinforcement was achieved by two independent variable-interval (VI) schedules operating across conditions throughout the experiment. Bizo and White (1995a) found that differential rates of reinforcement affected the pacemaker period, τ, (i.e., a pigeon's ability to estimate duration). For example, estimates of τ were largest on the left key when the differential reinforcement rate favoured left-key responses, whereas estimates were smallest on the right key when the differential reinforcement rate favoured this key.

Bizo and White (1994a) tested whether interreinforcer interval (IRI) durations affect the average interpulse time of an organism's pacemaker, a core assumption of BeT. In their first experiment, the IRI was manipulated by varying the VI schedule that was operating on the two response keys, left and right, throughout the experiment. The results showed that average interpulse time was affected by the IRI (e.g., when the IRI was increased and decreased, there was also an increase and decrease in the average interpulse time of an organism's pacemaker). A second experiment was conducted to test whether the availability or unavailability of reinforcement was affecting temporal discrimination. The procedure was the same as that in the first experiment except that responses for trials including reinforcers and those not including reinforcers were recorded, to show that changes in the average interpulse time, if a function of the IRI, would be observed for both the reinforcement and non-reinforcement trials. This was to counter the idea that pigeons may have been discriminating reinforcement occurrence, hence possibly confounding effects of the IRI. The results of this experiment showed that changes in interpulse time were a function of the IRI, independent of experimental events serving as discriminative stimuli for reinforcement (i.e., pigeons discriminating reinforcer occurrence). Results from both experiments support the BeT assumption that the IRI affects interpulse time.

Bizo and White (1994b) investigated whether reinforcement density influences the rate of an organism's pacemaker. Reinforcement density was altered separately in two experiments by varying the intertrial interval (ITI) and reinforcer duration. In Experiment 1 the ITI was varied using three different intervals in nine conditions. The pacemaker rate was affected by reinforcement density when the ITI was manipulated. In Experiment 2, reinforcement duration was manipulated to change reinforcement density but not the reinforcer frequency. When reinforcer duration is manipulated, reinforcer frequency remains constant, hence any changes in reinforcer duration are not confounded with reinforcer frequency when manipulating reinforcer density. Results from this experiment supported those from Experiment 1 and together both sets of results showed that reinforcement density affects pacemaker rate.

Fetterman and Killeen (1991) investigated, in two experiments, both using pigeons, how the probability and amount of reinforcement affects the speed of the pacemaker. In Experiment 1a pigeons performed a discrimination task and the magnitude and probability of reinforcement was manipulated. There were three key lights. At the start of the trial the centre key was illuminated red for a 4-s period ('short') or for a 12-s period ('long'). Upon the termination of the red key light, both the left and right response keys were illuminated with white light. Reponses to the left key, following a 4-s period, were correct and responses to the right key were correct following a 12-s period for half of the pigeons. The reverse was true for the other half of the pigeons. Correct responses resulted in 3-s access to reinforcement (grain) followed by a 10-s ITI. Incorrect responses initiated the ITI. The session ended when 50 reinforcers had been delivered. After the pigeons began to successfully discriminate (the training period), two procedural changes were made. Firstly, reinforcement was delivered for fifty-percent of correct responses made and the ITI was initiated for correct responses that were not reinforced. Secondly, a non-correction procedure was used, where stimuli were scheduled independently of the choice made on the previous trial. After the discrimination training ended, probe tests were conducted. Five probe trials comprised one half of the trials within each session and were presented equally often at arithmetically spaced durations. Reinforcement was delivered only for the non-probe trials, with equal presentations of the 'short' and 'long' stimulus conditions. Under probe testing (which began immediately after discrimination training ended), two manipulations were implemented. Firstly, the amount of the reinforcement (grain) that pigeons received was altered by changing the duration of the hopper cycle. The durations were in the following order: 3 s, 6 s, 1.5 s and 6 s. The second manipulation consisted of changing the reinforcement probability rate, so that correct responses were reinforced on either 20% or 80% of trials, counterbalanced across pigeons. Reinforcement duration and ITI access remained constant at 3 s and 10 s respectively. Probability levels were changed every ten sessions. On the .80 schedule, the session ended after 60 reinforcers had been delivered and on the .20 schedule, the session ended after 40 reinforcers had been delivered. Results of this experiment were not significant in that pigeons did not estimate time as predicted (i.e., the rate of the pacemaker was not increased).

In Experiment 1b, the ITI was varied to assess if this would affect the pigeons' timing behaviour. The procedure was similar to Experiment 1a, except for the following differences. A 10-s and a 100-s ITI were used and these were counterbalanced across pigeons and correct responses were reinforced at a .50 ratio. Pigeons were trained for 20 sessions with their respective ITI values before the probe trials began. The house light flashed on and off for 3 s preceding a trial to indicate to the pigeon that it should attend to the onset of the left or right key light (in the hope that the ITI would be incorporated into the reinforcement context). Sessions ended after fifty reinforcers had been delivered and the ITI was changed every ten sessions in accordance with an ABA design. Results were varied and did not show that the ITI had a significant effect on pigeon's timing behaviour.

In Experiment 2, a titration procedure was used where an adjustment was repeatedly made to the value of the longer stimulus. This enabled a comparison to be made with the constant short stimulus value, the difference between the two being a measure of timing accuracy. Thus, on each trial a standard signal (8 s) and a comparison signal were presented. The duration of the comparison signal was increased or decreased contingent upon how correct the pigeon's responses were and this constituted the titration procedure, where performance was established at a 75% correct criterion (e.g., if a pigeon responded correctly on 75% of the trials, then the comparison signal duration length was not changed). There were three groups; an ITI group, where the ITI was either 10 s or 100 s; an amount group, where pigeons had access to reinforcement for 1.5 s or 6 s, and a probability group, where correct responses were reinforced at a 25% or 75% probability. These manipulations were delivered using an ABAB design. Results showed that the manipulations of probability and amount of reinforcement influenced pigeons' timing behaviour as predicted by BeT, whereas manipulation of the ITI did not have the desired effect.

Morgan et al. (1993) also tested the hypothesis that changes in the rate of reinforcement will affect the rate of an internal pacemaker, as predicted by BeT. Pigeons were pre-trained on a temporal discrimination task, where responses on the left key were reinforced after a centre key was illuminated for 10 s (Short) and responses on the right key were reinforced after the centre key had been illuminated for 20 s (Long). In the first ten sessions, correct responses were reinforced and a 3-s blackout occurred for incorrect responses. A repetition of the trial was repeated for incorrect responding. During the last ten sessions, the probability of reinforcement for a correct response was reduced to 0.5 and a 3-s blackout followed responses made on the un-reinforced trials. Pre-training ended after forty sessions and each session ended after sixty reinforcers had been delivered. After pre-training, baseline responding was established. During this condition, correct responses were reinforced at a probability of 0.25 and on 75% of trials the short (10-s) and long (20-s) durations were presented. On the remaining 25% of trials, a 14-s probe was used to assess temporal discrimination. All responses were followed by a 3-s blackout. The average inter-food interval ranged between 60 s and 70 s. The baseline condition ended after twenty sessions, with sessions ending after sixty reinforcers had been delivered. The reinforcement rate was then manipulated by increasing and decreasing the length of the inter-food interval (IFI) (i.e., during a fast bias condition there was a 10-s IFI, whereas during a slow bias condition, the IFI was 60 s). Reinforcers were freely delivered and there were eight sessions. After reinforcement manipulation, pigeons were tested, by doing the temporal discrimination task in extinction (i.e., where responses were not reinforced) to measure the effects of the increased and decreased reinforcement rates. Each session had 112 trials and this condition ended after two sessions. After the testing condition, one session was conducted where reinforcement was made available to test pigeon's timing relative to the previous extinction condition. At the end of this condition, pigeons were placed back on baseline condition. Morgan et al. (1993) found that pigeons that were exposed to the higher rates of reinforcement, estimated time as slowing down and pigeons that were exposed to lower rates of reinforcement, estimated time as speeding up upon returning to baseline.

Bizo and White (1997) conducted a study that compared the predictive accuracy of two timing theories, scalar expectancy theory (SET) and BeT. SET assumes that temporal estimates involve information processing components. These components are an internal pacemaker, a comparator and memory. The pacemaker emits pulses which are counted by an accumulator. These counts are then stored in long-term or reference memory. Timing for animals occurs by comparing the pulse count in reference memory with the count in working memory (the count currently in the accumulator). Responses are based on the ratio between these two counts. Or in other words, an animal responds based on the ratio of an immediate expectancy of time to reinforcement to an overall expectancy of time to reinforcement. Thus, when the time interval between the local expectancy to reinforcement and the overall expectancy to reinforcement changes, animals rescale their time estimates in accordance with Weber's law. Weber's law, when applied to temporal perception, states that "the just noticeable difference, Δ, between two stimulus durations is a constant proportion, *k*, of d_o, the shorter of the two values" (Allan, 1979, p. 343). When the relative differences between two durations are held constant, according to Weber's law, they will be equally discriminable. Consequently, the standard deviation and the mean of temporal estimates are proportional to the timed duration (*T*). This results in the formation of a constant coefficient of variation (i.e., the Weber fraction) and is known as the scalar property. BeT predicts that the Weber fraction should decrease with increases in the interval being timed, whereas SET predicts that the Weber fraction should remain constant irrespective of trial duration length.

On a two-alternative free operant psychophysical procedure using pigeons, similar to that used previously (Bizo & White, 1995a; 1994a; 1994b), reinforcer density, total reinforcement duration divided by total session duration, was kept constant whilst the timing interval was varied. This allowed for the assessment of whether the Weber fraction would remain constant or not in accordance with the predictions of the two theories. Bizo and White (1997) found that the pacemaker rate varied contingent upon the length of the trial and not as a function of reinforcement rate as predicted by BeT (i.e., Weber's law was found to remain constant over those manipulations in accordance with the prediction of SET).

Procedural differences in other research have included putting pigeon's behaviour in extinction (Killeen, Hall & Bizo, 1999; Morgan, et al., 1993). Killeen et al. (1999) tested the prediction that, in extinction, the rate at which the internal pacemaker emits pulses would decrease. Using a standard operant chamber, pigeons were trained, during the baseline condition, to discriminate what response would lead to reinforcement. Two key lights were illuminated at the start of each trial. A response on the left key during the first 30 s of the trial was reinforced and a response on the right key was not. During the second 30 s of the trial a response on the right key was reinforced and a response on the left key was not. Each trial was separated by a 10-s ITI and reinforcement was delivered on a VI 40-s schedule. In the extinction condition, the only difference to the baseline condition was that responses on either of the two keys did not produce reinforcement. The results showed that during extinction the rate of the internal pacemaker slowed down compared to the rate at which pulses were emitted from the pacemaker during the baseline condition.

Morgan et al. (1993), who tested whether changes in the reinforcement rate affect changes in the pacemaker rate with pigeons, also tested, as part of their experimental procedure, the effect of zero reinforcement (i.e., extinction) on pigeon's temporal discriminative ability. Pigeons were exposed to higher and lower rates of reinforcement than those they had previously been exposed to in an initial baseline period and then were returned once more to the baseline condition. However, pigeons were also exposed to conditions where there was no reinforcement available. The results showed that during extinction the rate of the pacemaker slowed, as predicted by BeT.

Other studies have addressed how issues of the reinforcement context (e.g., the ITI and the type of stimulus used) affect the speed of the pacemaker (Beam, Killeen, Bizo & Fetterman, 1998; Bizo & White, 1995b; Fetterman & Killeen, 1991). In Fetterman and Killeen's (1991) study, the reinforcement context was the ITI, the duration of which was varied. A key light was used to signal to pigeons that the ITI was part of the reinforcement context. For example, if a pigeon's timing behaviour was affected by changes in the length of the ITI in an experimental session, then this may influence timing, in addition to the potential effects of reinforcer amount and probability (which this study also investigated). The manipulation of the ITI did not influence pigeons' timing ability. Thus, any effect of the reinforcement context was contingent upon whether or not the contextual changes are taken into account by the organism.

Beam et al. (1998) examined how the experimental context affects the speed of the pacemaker. This was achieved by varying how reinforcement was signalled to pigeons during a session. Two experiments were conducted and in both of them there were separate conditions that signalled reinforcement differently. In the first experiment, a standard operant chamber was used, where half of the trials began with the onset of a left key and half began with the onset of a right key. There were three conditions. In the first condition, the left key responses were reinforced on an FI 20-s schedule and right responses were reinforced on a FI 40-s schedule. The second condition was the same as the first except that only the left or the right key was lit throughout the session, rather than alternating illumination across keys as it was done in the first condition. The third condition replicated the first condition. In the second experiment, a psychophysical procedure was used where pigeons pecked either a left or right key to distinguish between either a short or a long duration. Reinforcement was delivered when a correct choice was made. Results from both experiments showed that different experimental contexts affected changes in the pacemaker speed of the pigeons by signalling changes in the reinforcement rate using strong discriminative stimuli.

Bizo and White (1995b) tested whether changes in the rate of the pacemaker were a function of reinforcers from different contexts (i.e., reinforcers that were not directly related to temporal estimation). In a free operant psychophysical procedure, pigeons responded on the left or the right key of a 50-s trial. Reinforcement was delivered on the left key for the first 25 s of the trial and on the right key for the second 25 s of the trial, using independent variable interval schedules. There were fourteen conditions. In the first three conditions, reinforcement on the left and right keys was delivered according to a VI 60-s schedule. Extraneous reinforcement (reinforcers that are unrelated to temporal estimation) was also delivered when the centre key was illuminated red during the ITI only, independent of reinforcement delivered on the side keys. Delivery of reinforcement during the ITI was on a VI 10-s schedule in Conditions 1 and 3 and on a VI 20-s schedule in Condition 2. In Conditions 4 to 9, VI 50-s schedules were used on the left and right keys. Extraneous reinforcement was delivered throughout both the trial and the ITI, on VI 240-s, VI 120-s (for two conditions), VI 60-s and VI 30-s schedules. There was also an extinction condition. In Conditions 10 to 14, VI 50-s schedules were used on the left and right keys. Extraneous reinforcement was delivered throughout the trial only, on VI 240-s (for two conditions), VI 60-s and VI 30-s schedules. There was also an extinction condition. Bizo and White (1995b) found that changes in the pacemaker rate were contingent upon changes in the reinforcement rate that were directly related to the temporal discrimination an organism makes and not to reinforcers from other contexts not directly associated with the estimation task.

The animal studies that have just been described, investigated the timing abilities of pigeons from a BeT perspective. The results of these studies suggest that BeT provides a functional and reliable explanation of animal timing behaviour. Manipulation of the reinforcement rate does affect an organisms' perception of time passing. It remains to be seen however, whether BeT can explain human timing behaviour as reliably as it explains animal timing behaviour. The next set of studies to be described have investigated timing from a BeT perspective for humans, as well as comparing timing abilities across species.

Wearden et al. (1999) manipulated the rate of a hypothesised internal clock in humans. A click-train technique (Triesman, Faulkner, Naish & Brogan, 1990) was used, where a train or series of repetitive stimuli (i.e., clicks) preceded a target stimulus (e.g., a tone). When a click-train preceded the target stimulus, the rate of the internal pacemaker would speed up (Wearden et al., 1999). The procedure involved the presentation (using a computer and speakers) of a standard and a comparison stimulus (a tone). Participants pressed the space bar on the computer keyboard to begin a trial. A 5-s delay followed the spacebar press before the presentation of the standard tone. Following the end of the standard presentation, a 5-s delay period occurred, before the presentation of the comparison tone. The standard and comparison stimulus were both of equal duration. The delay period could either be silent or filled by clicks (1000 Hz tones, 10 ms long). Participants were asked whether the comparison tone was longer or shorter than the standard tone. The overall conclusion was that when clicks preceded the comparison stimulus the pacemaker rate slowed down, whereas the pacemaker rate sped up when clicks preceded the standard stimulus.

The differences in how pigeons and humans estimate time has also been investigated (Fetterman, Dreyfus & Stubbs, 1989; 1993; 1996). The basic procedure used in these three studies has required pigeons and humans to compare two different durations, indicating which duration length was longer or whether it was the same or different. In some cases, the differences in duration were also based on a criterion ratio, where a judgment was made indicating whether the difference between the two durations was less than or greater than a certain ratio (e.g., 3:1). In other cases, judgments were based on instructional rules, where information was provided to participants, prior to the commencement of trial, about the choice participants had to make about the duration lengths. Fetterman et al. (1989; 1993; 1996) found that humans judged durations on ratio-based tasks less accurately than pigeons, whereas humans could judge more accurately than pigeons which task was longer or shorter in a straight comparison trial. Instructional information also affected performance, where the estimates of participants who were told about the different relational rules of their trials, were more accurate for the ratio and same-different judgements than the estimates of participants who were not given information.

In another study comparing the behaviour of species, Fetterman and Killeen (1992) used psychophysical procedures in four experiments to assess the abilities of humans and pigeons to discriminate small duration intervals. For pigeons, a standard three-key operant chamber was used. At the beginning of a trial, a peck to the illuminated centre key light extinguished it. A delay was now operating and when it timed out, the two side keys were lit. Pigeons then pecked the left key if the delay had been short or pecked the right key if the delay had been long. Correct responses were reinforced by receiving 3-s access to grain, followed by a 10-s ITI. Humans were verbally told a description of the task and were seated in a dark room, with panels that could be reached and pressed, analogous to the operant chamber for pigeons. The programming was the same as that used for the pigeons. Correct responses resulted in a 300-ms feedback flash of the house-light, followed by a 1-s ITI. The ITI directly followed an incorrect response.

In Experiment 1, humans and pigeons discriminated between whether a fixed short duration or a longer variable duration period had been presented to them. In Experiment 2, pigeons repeated the same task as in Experiment 1 but with different durations for the short and long periods on fifty percent of the trials within a session. On the remaining fifty percent of trials, which were un-reinforced probe trials, pigeons discriminated duration periods that ranged between the duration lengths used in the discrimination trials. Experiment 3 tested whether changes in non-temporal cues (i.e., the brightness of the centre key light) were affecting pigeon's temporal estimates but it was found that non-temporal cues were not affecting estimates. In Experiment 4, pigeon's timing ability was tested at very small duration periods (which ranged from 0 ms to 1 s) and it was found that pigeons do maintain constant accuracy at these duration intervals. Fetterman and Killeen (1992) claimed that, overall, the results from the four experiments showed that estimates of duration between the two species were comparable.

The animal and human studies on timing described above had as their theoretical foundation, BeT. BeT is one theoretical approach that has been used, predominantly in animal studies, but also in human studies to explain temporal perception. The results of the timing studies described above suggest that BeT provides a theoretical basis from which to make predictions about animal and human estimates of duration. In the context of doing a jigsaw puzzle, it might be that a reinforcer is successfully moving a puzzle piece. When a puzzle piece is moved, a participant gets feedback on whether the move resulted in further completion of the puzzle or not. Thus, manipulation of the number of pieces that can be moved per unit time could be argued to be equivalent to manipulation of the reinforcement rate.

In the first series of task complexity experiments, attempts were made to vary task complexity by increasing and decreasing the number of puzzle pieces in the jigsaw puzzle. There was no difference in the number of puzzle pieces able to be moved per unit time between the simple and complex conditions, since the rate or speed at which puzzle pieces could be moved was not manipulated. Thus, it may be that because no attempt was made in the first series of task complexity experiments to control the number of puzzle pieces that could be moved per unit time, thereby affecting the reinforcement rate, that subsequent estimates of duration made by participants were not as expected. According to BeT, simply changing the number of puzzle pieces in the jigsaw will not affect changes in the reinforcement rate. The next series of experiments was designed, based on the behavioral theory of timing principles, to manipulate the reinforcement rate provided by the jigsaw task, to assess the effect this had on participants' estimates of duration.

EXPERIMENT 7

The aim of this experiment was to try and manipulate the rate of reinforcement provided by the jigsaw puzzle to see if this would affect participants' estimates of duration. Sumpter and McEwan (2003) found that, with humans, visual perceptual outcomes (i.e., moving pieces within a computer generated jigsaw puzzle such as the present one) maintained behaviour within an experimental session. In their study, participants were required to do a 25-piece computer generated jigsaw puzzle. Participants had to click the computer mouse button several times, depending on the condition operating, to enable a puzzle piece to be moved. The number of clicks was increased from 2 to 512 within the session. Participants continued responding to move the puzzle pieces at these high response requirements. Sumpter and McEwan (2003) argued that the periodic presentation of perceptual outcomes can serve as reinforcers for adult humans in the same way as traditional reinforcers, such as food and water do for animals. In another study, Case (1995) used a popular computer generated game (i.e., Star Trek) to examine observing behaviours, which Dinsmoor (1983) suggested are attentional responses maintained by the informative properties of stimuli. Participants were required to engage enemy forces and defend themselves. The reinforcing stimuli were the discovery and destruction of enemy forces. Case (1995) argued that such technologies, once standardised through further research and testing, would allow for the valid experimental manipulation of reinforcement contingencies to conduct human operant research. It was assumed for the present study that the movement of a puzzle piece to a new location provided the reinforcement that maintained behaviour on the jigsaw task. If this assumption is correct, then moving more pieces in a set time should be equivalent to gaining a higher rate of reinforcement and moving fewer pieces should be equivalent to a drop in reinforcement rate.

In testing the BeT prediction, that reinforcement rate affects an organism's perception of time passing, several changes were required to the procedures used in the previous task complexity experiments. First, the complexity dimension was removed, as complexity was no longer being manipulated. Second, the number of estimates made was increased. For this experiment, the session was divided up into four 12-min long experimental conditions. The attempt to manipulate reinforcement rate involved decreasing the distance that a puzzle piece could be moved on the computer screen relative to the distance which the computer mouse was moved. This manipulation should result in a decrease in the number of pieces that could be moved within the session. Given the fact that each condition was in effect for 12 min here, the numbers of pieces moved in a condition is directly equivalent to the rate of movement, and so the number of pieces moved in a condition will be referred to as the rate of movement or rate of reinforcement. As in the previous experiments, the participants had to estimate the duration of various time intervals as this had been found, in earlier experiments, to be a reliable way of obtaining estimates of duration. The final procedural change consisted of getting participants to record their estimates on a flip sheet pad. This was to avoid any effect that the previous estimate might have had on the next one. It was hoped that the results of this experiment would show if the rate of moving pieces affects a person's perception of time passing.

Method

Participants

Twelve participants were recruited as in Experiment 1. They are referred to as P7.1 to P7.12.

Apparatus

The apparatus was the same as that used in Experiment 1.

Procedure

The procedure was similar to that used in Experiment 4 except for five differences. A thirty-six piece puzzle was always displayed and the number of estimates that participants were required to make was increased from 32 to 48. The session was divided into four 12-min conditions and in each condition the participants were asked to estimate the time that had passed from the last estimate 12 times. The interval durations that were required to be estimated are given in Table 7.1 in the order they were presented in each condition. The order of the intervals in the third condition was the same as those in the first condition and the order of the intervals in the fourth condition was the same as those in the second condition.

Table 7.1

Intervals and the order in which they were presented, for each 12-minute condition at which participants estimated duration.

Interval durations			
12-min Conditions (in seconds)			
1	2	3	4
60	30	60	30
30	120	30	120
15	45	15	45
90	60	90	60
45	15	45	15
120	90	120	90
15	45	15	45
90	120	90	120
30	30	30	30
45	90	45	90
120	15	120	15
60	60	60	60

There was a proportional linear relationship between the distance a puzzle piece could be moved and the movement of the computer mouse. That is, the distance the computer mouse-ball travelled when moved by a participant resulted in a smaller distance travelled by the puzzle piece when the cursor was placed over a puzzle piece. The proportional relationship was changed depending on which experimental condition was in effect. In Condition 1, the distance travelled by the puzzle piece was slowed to one-half of that of the computer mouse. In Condition 2, the distance travelled was slowed to one-quarter of that of the computer mouse. In Condition 3, the distance was slowed to one-eighth of that of the computer mouse and in Condition 4, it was slowed again to one-half of the distance travelled of that of the computer mouse.

Participants recorded their time estimates on a flip sheet pad, where each page was turned or 'flipped' over once an estimate was recorded. The estimation method, where participants engage in a task and then estimate how long they think they have been doing that task, when prompted, was used throughout the entire experiment. As in the previous experiments, participants were escorted into the computer laboratory by the Experimenter. Each participant sat down at a computer and was asked to read the sheet of instructions. The instructions were as follows:

Introduction:

This experiment involves working with jigsaw puzzles where you move pieces around to complete a picture. You will be required to estimate the time you think you have been working on the puzzle. Please read the steps below to familiarise yourself with the experimental procedure.

Step 1: In the experiment, a puzzle with a number of squares will be displayed on the computer screen. Each of these squares is part of a picture you will see in the top left hand corner of the computer screen. Your task is to use the mouse to move the pointer over a square and depress the left mouse button to drag that square to a new location. You can repeat this until you have completed the puzzle.

Step 2: Throughout the experiment a box will appear in the centre of the computer screen asking you to estimate how long you think you have been doing the puzzle. You may write your estimate in terms of minutes or seconds or both on the flip pad provided. Once you have written down your estimate on the flip pad turn the page over in preparation for writing down the next estimate. Now use the mouse to move the pointer over the 'Continue' button situated below the estimation instructions and depress the left mouse button to start the puzzle again. If you have any questions please ask them now. You may start the experiment by using the mouse to move the pointer over the 'Start' button and depress the left mouse button to begin.

Once any questions were answered, the Experimenter asked the participant to remove their watch, if they were wearing one, and informed the participant that it would be returned at the end of the experiment. The Experimenter then told the participant they could start when ready. The Experimenter remained in the room. No further communication between the Experimenter and the participant occurred until the end of the session, when the participant was debriefed as to the aim of the experiment.

Results

Figure 7.1 shows the logarithms of the estimates over the actual times at which participants were required to make their estimates, in each condition, plotted against the number of successive estimates made throughout the session. Figure 7.2 shows the averages of these logarithms for each condition. It was expected that participants would estimate duration as passing more slowly in C2, where the distance travelled by the puzzle piece in proportion to the distance travelled by the computer mouse was less than the distance travelled in C1 and C4, and that they would estimate time as passing even more slowly in C3 than in C1, C2 or C4. This would be seen by more overestimation (i.e., higher data points, in C2 than in C1 and C4) and even more overestimation (i.e., even higher data points) in C3 than in C1, C2 and C4.

The data in Figure 7.1 are very variable within each condition. Between conditions, there are some cases where C2 data tend to be higher than C1 data (e.g., P7.3, P7.5 and P7.6) and some where C3 data tend to be higher than C2 data (e.g., P7.5 and P7.8) as was predicted. In no case do the data increase over C1 to C2 to C3 and then decrease again in C4. In fact, the data vary somewhat unsystematically across participants and conditions. The mean data in Figure 7.2 confirm that what differences there were between conditions were small and that any changes across conditions were unsystematic.

A two-way repeated measures ANOVA was performed, with the manipulation of the computer mouse and the time at which estimates were made, as within-subject variables. The ANOVA compared the means of the logarithms of the estimates over the actual times at which participants were required to make their estimates, for the computer mouse manipulation and for the actual times at which estimates were made. There was no main effect of the distance at which the computer mouse was moved upon the participants' estimates of duration ($F(3, 33) = 1.660$, $p > .05$) and the effect size was small ($\eta = .131$). There was a main effect of the times at which estimates were made ($F(5, 55) = 5.221$, $p < .05$) and the effect size was small ($\eta = .322$). Pairwise

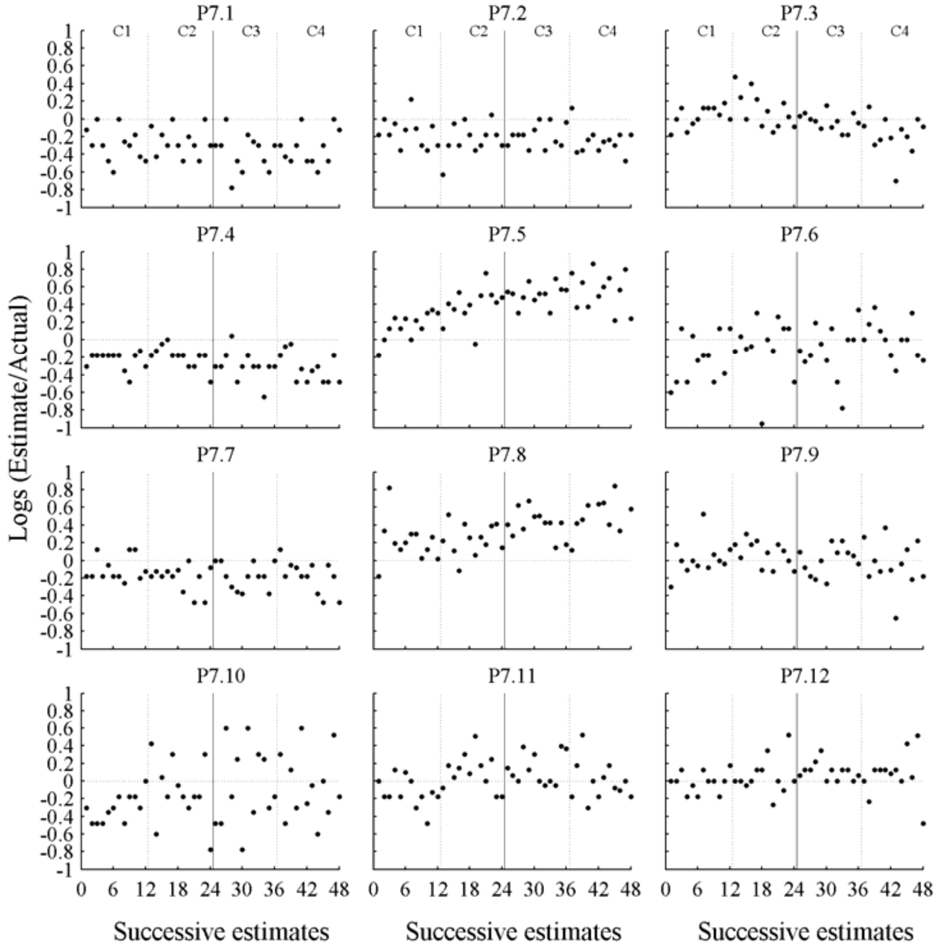

Figure 7.1. Logarithms of the estimates over the actual times for each condition, plotted against the successive number of estimates made in the session. C1, C2, C3 and C4 indicate the proportional relationship between computer mouse and puzzle peice movement.

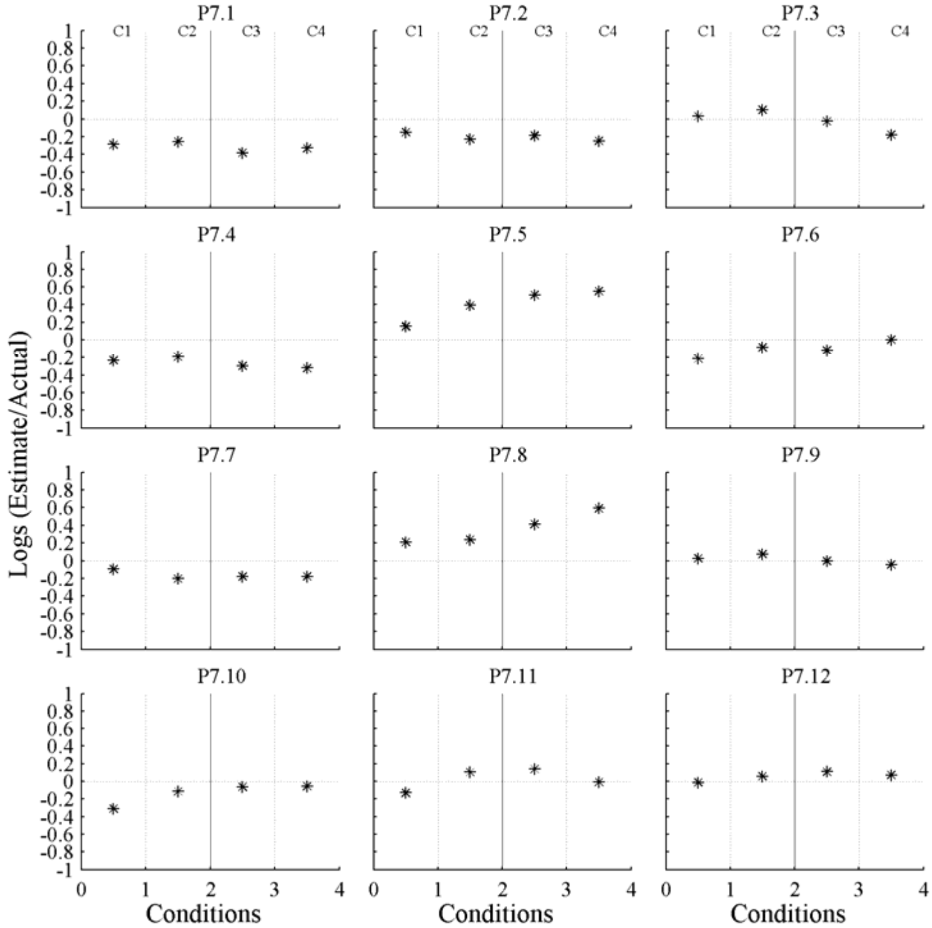

Figure 7.2. Averages of the logarithms of the estimates over the actual times, plotted against each experimental condition. C1, C2, C3 and C4 indicate the proportional relationship between computer mouse and puzzle peice movement.

comparisons showed that the log ratios from the 15-s interval were significantly different to those from the other intervals ($p < .05$). There was no interaction between the distance the computer mouse was moved and the times at which estimates were made (F (15, 165) = .928, $p > .05$).

Figure 7.3 shows the logarithms of the estimates over the actual times, together with the 95-percent confidence interval, averaged over all participants' data, plotted against the actual times. The log ratios show that participants' estimates of duration tended to decrease as the times at which estimates were made increased, although it appears that estimates did not continue to decrease from the 60-s interval onwards. Duration was overestimated more at the 15-s interval than for any of the other intervals.

Figure 7.4 shows the total number of pieces moved by each participant in each condition in the experiment. All but P7.1, P7.6, P7.7 and P7.10 moved more pieces in Condition 2 than in Condition 1. P7.1 and P7.10 moved fewer pieces in Condition 2 than in Condition 1 and P7.6 and P7.7 moved the same number of pieces in Condition 2 as in Condition 1. All but P7.1, P7.2, P7.10 and P7.11 moved fewer pieces in Condition 3 than in Condition 2. P7.10 moved more pieces in Condition 3 than in Condition 2. P7.1, P7.2 and P7.11 moved approximately the same number of pieces in Condition 3 and Condition 2. In Condition 4, all participants moved more pieces than in any of the previous three conditions. A one-way repeated measures ANOVA was performed, with the number of pieces moved in each condition as the within-subject variable. The ANOVA compared the number of pieces moved for the computer mouse manipulation. There was a main effect of the computer mouse manipulation on the number of pieces that could be moved (F (3, 44) = 5.696, $p < .05$) and the effect size was small (η = .280). Pairwise comparisons showed that the numbers of pieces moved in Condition 4 were significantly different from the numbers moved in the other three conditions ($p < .05$). The number of pieces moved in Condition 3 were not significantly different from the numbers moved in Conditions 1 and 2 ($p > .05$) and the numbers of pieces moved in Condition 1 were not significantly different from the numbers moved in Condition 2 ($p > .05$).

Discussion

In this experiment, an attempt was made to manipulate the rate of moving the jigsaw pieces (i.e., the reinforcement rate). The results showed however, that the

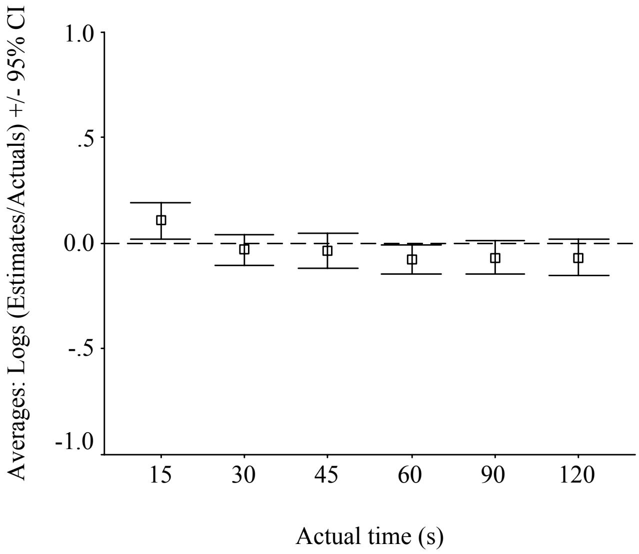

Figure 7.3. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, plotted against the times at which estimates were made.

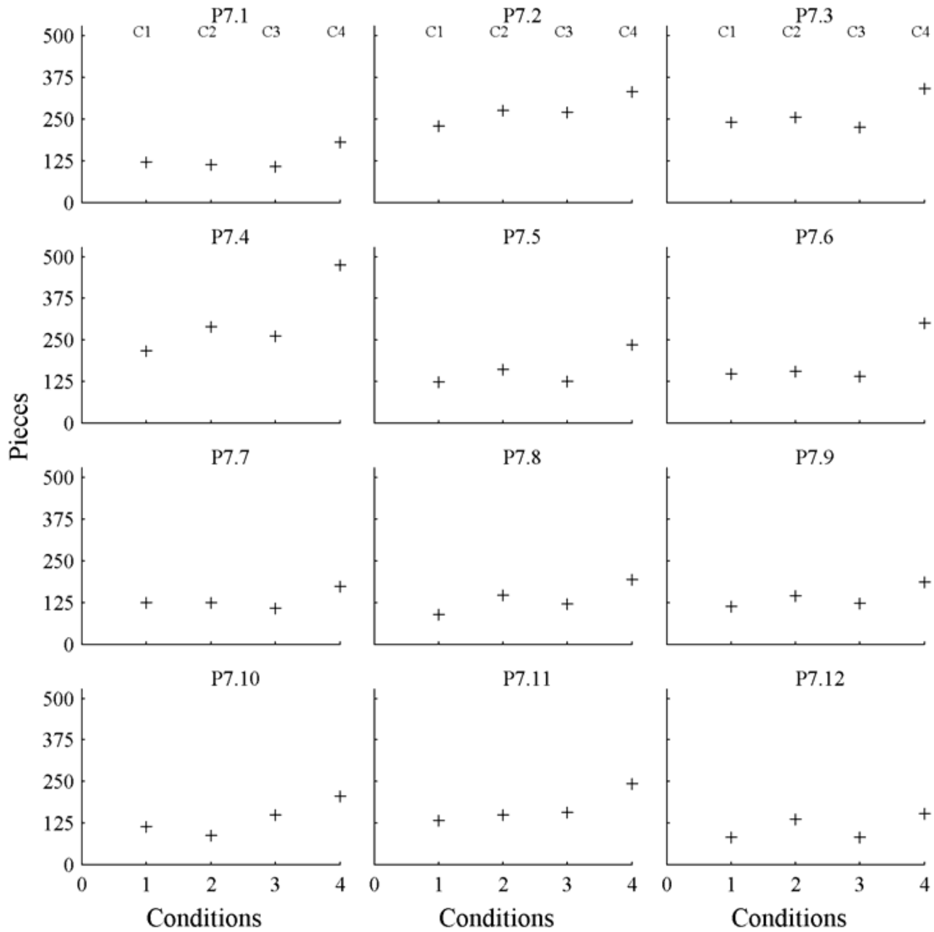

Figure 7.4. Number of pieces moved, plotted against each experimental condition. C1, C2, C3 and C4 indicate the proportional relationship between computer mouse and puzzle peice movement.

reinforcement rate was not manipulated as expected. In fact there were no consistent differences in the number of pieces moved in Conditions 1, 2 and 3, when a reduction in Condition 2 and in Condition 3 had been expected. In addition, the ANOVA results and Figure 7.3 showed that significantly more pieces were moved in Condition 4, than in any of the previous three conditions. It had been expected that the number of pieces moved in Condition 4 would be the same as the number of pieces moved in Condition 1 because the distance the computer mouse could be moved in Condition 4 was the same as in Condition 1. However, the actual obtained rate of movement was the fastest in Condition 4. As mentioned earlier in this thesis, Morgan et al. (1993) found that pigeons exposed to a high rate of reinforcement estimated duration as longer upon returning to baseline (with lower reinforcement rates) than did pigeons returning to baseline after being exposed to lower reinforcement rates. Thus, it might be expected that, as participants moved more pieces in Condition 4 once the restrictions were removed, time would be estimated as going faster. That there were no consistent differences in the relative estimates of duration in Condition 4 as compared to the other three conditions, suggests that the participants' estimates of duration were not affected by this ability to increase the number of pieces moved.

In this experiment, there was an effect of the actual times at which estimates were made on participant's estimates of duration at the 15-s interval. This result is similar to the results from Experiments 3 and 4, where there was also an effect of the actual times at small intervals (e.g., 30 s). Thus, it appears that participants have a tendency towards overestimating duration more after a short time interval than after the longer ones (see Figure 7.3).

BeT suggests that as the rate of reinforcement is reduced, an organism perceives duration to pass slower than if the reinforcement rate is increased. In this experiment, the attempt to manipulate reinforcement rate did not work as planned and the participants' estimates were not affected by controlling the distance that the computer mouse could travel. The failure of the change in relative distance to reduce the number of pieces moved suggests that, in Conditions 2 and 3, participants were compensating for the experimental manipulation. In addition, the increase in the number of pieces moved in Condition 4 (over and above the number moved in Condition 1) suggests that participants may have learnt that they needed to move the computer mouse greater distances before a puzzle piece could be successfully moved, and that this learning carried on into Condition 4. Given the failure to manipulate the number of pieces moved in predictable directions, a new procedure was needed to ensure that the participants could not compensate for the experimental manipulation. With better experimental control over the number of pieces that could be moved, it would be possible to test whether there is an effect of the reinforcement rate on human's estimates of duration. The next experiment was designed to do this.

EXPERIMENT 8

In the previous experiment participants appeared to learn to compensate for the reduced relative movement of the jigsaw pieces by moving the computer mouse faster. This next experiment aimed to remove the opportunity for participants to do this by setting the maximum speed at which a puzzle piece could be dragged. It was hoped that this would reduce the number of pieces that could be moved during the intervention conditions. This manipulation was chosen as it proved impossible to develop a workable method to control for the number of pieces moved directly. The maximum speed was determined based on tests conducted by the Experimenter prior to the experiment commencing. In the tests, the maximum number of pieces that could be moved during each of five 60-s trials was established. The Experimenter's test average was then used as the basis for setting the maximum speed a puzzle piece could be dragged in Condition 2, the first of the two intervention conditions. Thus, in Condition 2, the maximum speed was set to half of the speed used in Condition 1 by the Experimenter when he established his test average. The maximum speed in Condition 3 was set to be half of the speed employed in Condition 2. Thus, with the maximum drag speed fixed to be half of that the Experimenter achieved pre-experimentally, a participant should have been able to move only half as many puzzle pieces as the Experimenter had been able to per unit time. It was hoped that this change would reduce the number of pieces that a participant could move compared to the number they moved without this restriction. It was recognised, however, that the degree to which the number moved depended on the free-rate of movement of the participant. For example, if a participant moved the cursor at a slower rate than the new maximum when not restricted, then this manipulation would have little effect. It was also recognised that slightly more pieces could be moved if a participant moved pieces only short distances. It was expected that the participants would work on the puzzle in the usual manner by moving pieces all around the computer screen. It was hoped that the maximum speed restrictions would reduce the number of pieces moved (i.e., the reinforcement rate) and so affect how participant's estimated duration.

Method

Participants

Ten participants were recruited as in Experiment 1. They are referred to as P8.1 to P8.10.

Apparatus

The apparatus was the same as that used in Experiment 1.

Procedure

In this procedure, as in Experiment 7, participants made 48 estimates of duration, twelve in each 12-min condition and they recorded their estimates on flip-sheet pads. The major difference from Experiment 7 was that the maximum speed at which each puzzle piece could be dragged in Conditions 2 and 3 was fixed. This meant that participants could not move the computer mouse faster than this maximum in an attempt to increase their reinforcement rate. In Conditions 1 and 4, there were no speed restrictions. As previously mentioned, the maximum speed at which the computer mouse could be moved was derived from pre-experimental tests conducted by the Experimenter. The Experimenter's test average was 96 (i.e., the maximum number of pieces he could move in a 60-s trial, averaged across five trials). Based on this average, the maximum speed at which a puzzle piece could be dragged in Condition 2 was set so that only half as many pieces could be moved in Condition 2 as the Experimenter moved in Condition 1 (i.e., his test average). The number entered into the computer jigsaw programme file to set the maximum speed in Condition 2 was completely arbitrary, in that any number could have been used as long as it set the maximum speed. To determine the number that was to be used to set the maximum speed in Condition 2, the Experimenter conducted more pre-experimental tests (i.e., ten 60-s trials) until he was satisfied that he could only move as half as many pieces as he moved in Condition 1. In Condition 3, the drag speed was set so as to be half of that in Condition 2, by simply halving the number that was used in the computer jigsaw programme file in Condition 2. This change again reduced the number of pieces could be moved by participants compared to Condition 2. In Condition 4, as in Condition 1, there were no drag speed restrictions.

As in the previous experiments, participants were escorted into the computer laboratory by the Experimenter. Each participant sat down at a computer and was asked to read the same sheet of instructions used in Experiment 7. Any questions were answered and the Experimenter asked the participant to remove their watch, if they were wearing one, and informed the participant that it would be returned at the end of the experiment. The Experimenter then told the participant they could start when ready. The Experimenter remained in the room. No further communication between the Experimenter and the participant occurred until the end of the session, when the participant was debriefed as to the aim of the experiment.

Results

Figure 8.1 shows the logarithms of the ratios of the estimates over the actual times at which participants were required to make their estimates, in each condition, plotted against the number of successive estimates made throughout the session. Figure 8.2 shows the averages of these logarithms for each condition. It was expected that participants would estimate time as passing more slowly in C2, where the drag speed was half of that in C1 and C4, and that they would estimate time as passing even more slowly in C3 than in C1, C2 or C4. This would be seen by more overestimation (i.e., higher data points, in C2 than in C1 and C4) and even more overestimation (i.e., even higher data points) in C3 than in C1, C2 and C4.

The data in Figure 8.1 are very variable within each condition. Between conditions, there are some cases where C2 data tend to be higher than C1 data (e.g., P8.6, P8.7, P8.9 and P8.10). However, it appears that time was not estimated as going slower in C3 than in C2 (as was expected) because the data in C3 do not tend to be higher than the data in C2. The mean data in Figure 8.2 confirm that the changes across conditions were unsystematic and that the differences there were between conditions were small.

A two-way repeated measures ANOVA was performed, with the manipulation of the drag speed and the time at which estimates were made, as within-subject variables. The ANOVA compared the means of the logarithms of the estimates over the actual times at which participants were required to make their estimates, for the drag speed manipulation and for the actual times at which estimates were made. There was no main effect of the

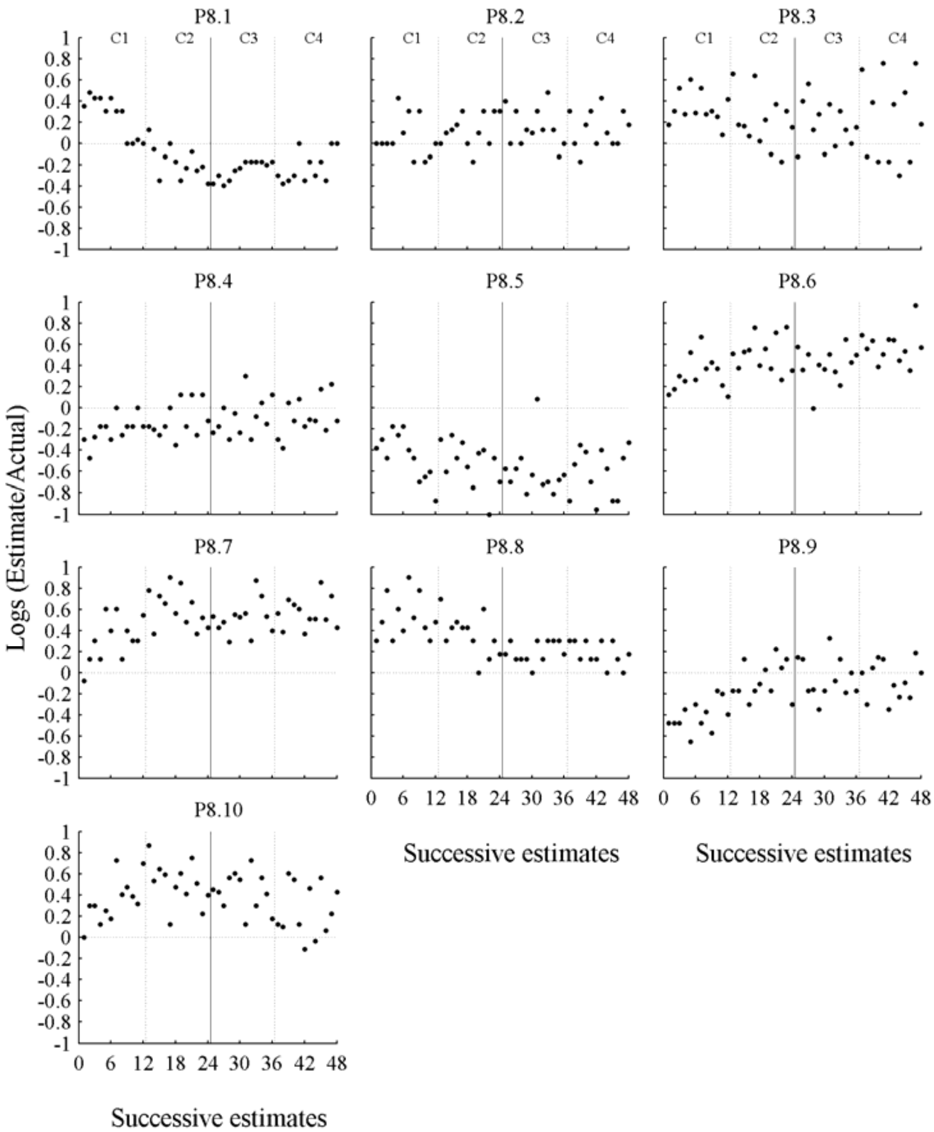

Figure 8.1. Logarithms of the estimates over the actual times for each condition, plotted against the successive number of estimates made in the session. C1 and C4: no speed restrictions; C2 and C3: speed restrictions.

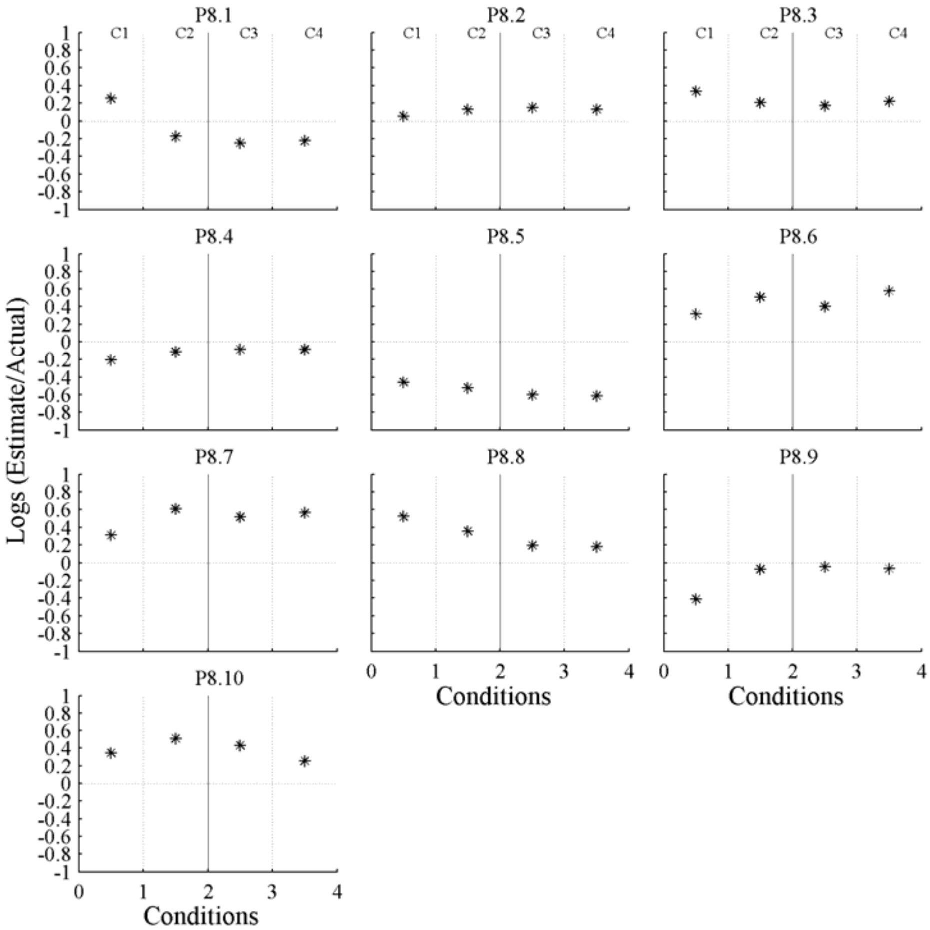

Figure 8.2. Averages of the logarithms of the estimates over the actual times, plotted against each experimental condition. C1 and C4: no speed restrictions; C2 and C3: speed restrictions

speed at which a puzzle piece could be dragged, upon the participants' estimates of duration (F (3, 27) = .340, p > .05) and the effect size was small (η = .036). There was a main effect of the times at which estimates were made (F (5, 45) = 10.909, p < .05) and the effect size was medium (η = .548). Pairwise comparisons showed that the log ratios from the 60-s interval were significantly different to those from the other intervals and the log ratios from the 15-s interval were significantly different to those from the 90-s and 120-s intervals (p <.05). Log ratios from the 90-s interval were significantly different to those from the other intervals (p <.05) except the 120-s interval. There was an interaction between the speed at which puzzle pieces could be dragged and the times at which estimates were made (F (15, 135) = 2.502, p < .05) and the effect size was small (η = .218).

Figure 8.3 shows the logarithms of the estimates over the actual times estimated, together with the 95-percent confidence interval, averaged over all participants' data, plotted against the actual times. The log ratios of participants' estimates of duration tended to decrease as the times at which estimates were made increased, although at the 120-s interval estimates increased compared to those from the 90-s interval. Duration was overestimated more at the 15-s interval than for any of the other intervals.

Figure 8.4 shows the total number of pieces moved in each condition by each participant. All participants moved fewer pieces in Condition 2 than in Condition 1 and fewer pieces in Condition 3 than in Condition 2. In Condition 4, all participants moved more pieces than in any of the previous three conditions. A one-way repeated measures ANOVA was performed, with the number of pieces moved in each condition as the within-subject variable. The ANOVA compared the number of pieces moved for the drag speed manipulation. There was a main effect of the computer mouse manipulation on the number of pieces moved (F (3, 36) = 25.159, p < .05) and the effect size was large (η = .677). Pairwise comparisons showed that the numbers of pieces moved in C4 were significantly different from those moved in C1, C2 and C4 (p <.05). The number of pieces moved in C1 were significantly different from the number moved in C3 (p <.05).

Discussion

In this experiment, a procedure that fixed the maximum speed at which a puzzle piece could be dragged was used to try and reduce the number of pieces moved, while, at the same time, reducing the ability of participants to compensate for this reduction. As

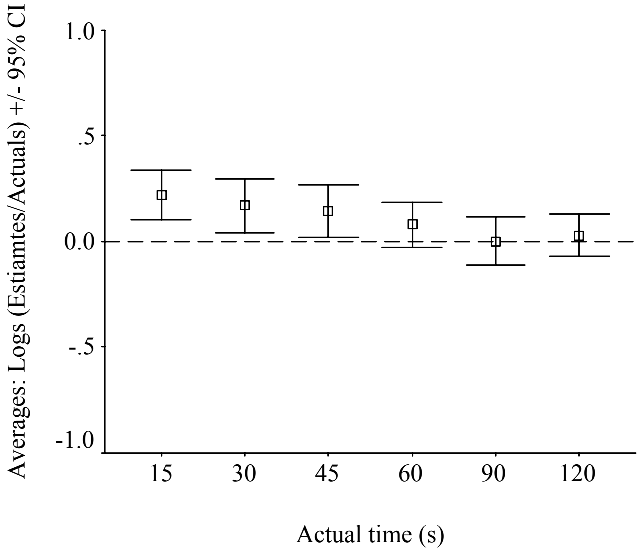

Figure 8.3. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, plotted against the times at which estimates were made.

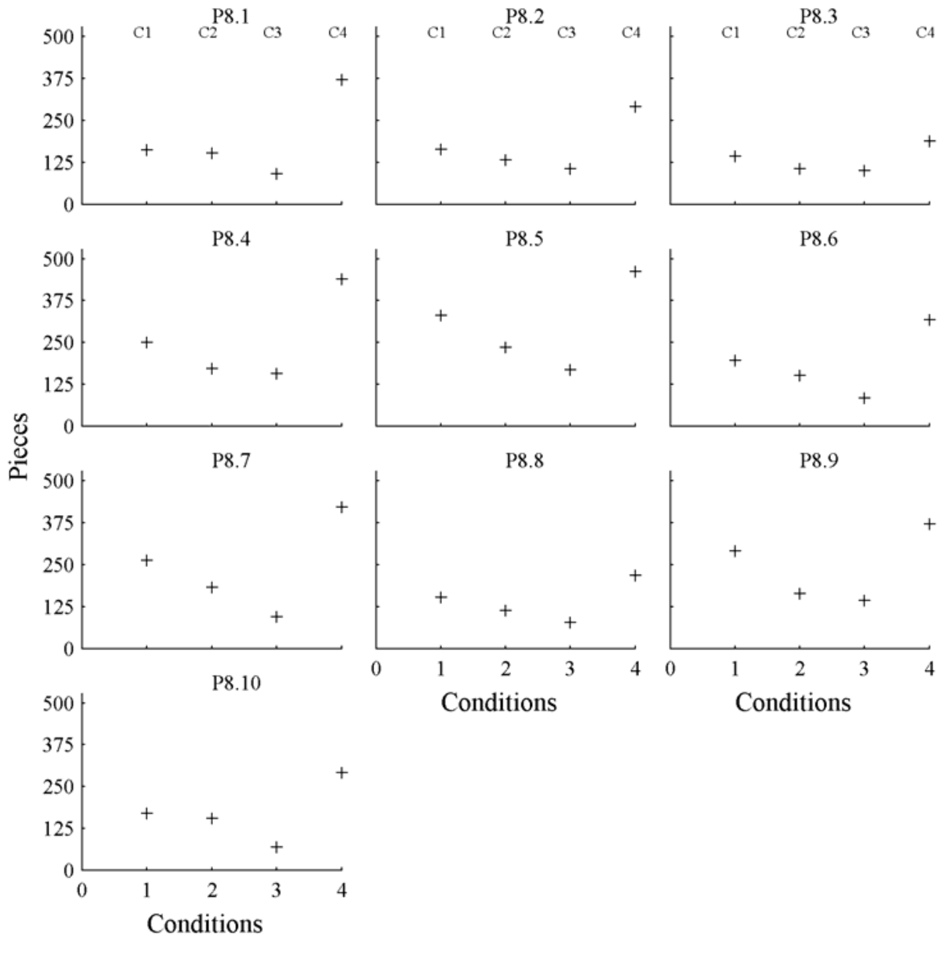

Figure 8.4. Number of pieces moved, plotted against each experimental condition. C1 and C4: no speed restrictions; C2 and C3: speed restrictions.

shown in Figure 8.4, in Conditions 2 and 3, where the maximum speed was fixed, fewer pieces were moved. However, despite the fact the reinforcement rate was successfully manipulated, Figure 8.1 and the ANOVA results show that there was no effect on participants' estimates as would be predicted from BeT. Slowing down the maximum speed at which a puzzle piece could be moved did not affect the participants' estimates of time passing in any consistent way.

In this experiment, there was an effect of the actual times at which estimates were made on participant's estimates of duration. As in the previous experiment and in Experiments 3 and 4, Figure 8.3 showed that participants tended to continue underestimating duration as the actual times at which estimates were made increased.

The behaviour of the participants doing the jigsaw puzzles was observed by the Experimenter during the experimental session. The Experimenter observed that the way the participants moved the computer mouse was quite varied once the restriction started. For example, some participants lifted the computer mouse from the mouse-pad and then forced it back onto the mouse-pad very quickly during Conditions 2 and 3. The Experimenter also heard other participants make barely audible verbal comments to themselves that the computer mouse was not working during both of these conditions. Thus, in the restricted speed conditions participants appeared to be changing their behaviour in an attempt to counteract the effects of the restriction. The participants continued to attempt to do the jigsaw puzzle, even though during the manipulation condition they could not move as many puzzle pieces compared to the non-manipulation conditions. It is possible that these changes in behaviour counteracted any effects of the speed manipulation on their estimates of duration. For example, it might be possible that, like the participants in Experiment 7, these participants were also trying to compensate for the speed manipulation (even though the variable behaviour observed by the Experimenter would not result in more pieces being moved, since the drag speed was fixed). The data in Condition 4 of Figure 8.4 show that more puzzle pieces were moved once the restrictions were lifted hence, it appears that the changes in the participants behaviour in Condition 2 and Condition 3 carried over into Condition 4.

In this experiment, the manipulation (i.e., reduction) of the reinforcement rate by fixing the maximum speed at which a puzzle piece was dragged was successful but this did not affect the participants' estimates of duration. It might be possible that this type of manipulation does not signal to participants that there has been a change in the reinforcement rate. Humans have a history of working with computers. Perhaps a manipulation of a stimulus with which humans are more familiar with is required. For example, something that is analogous to the computer hour-glass icon that appears and signals to a computer user that a waiting period is required before continuing. If such a manipulation is successful, then perhaps participants will estimate duration as expected, or predicted by BeT. The next experiment tested this possibility.

EXPERIMENT 9

In the previous experiment, the speed at which a puzzle piece could be dragged was fixed so that the participants could not compensate for the manipulation of the reinforcement rate (as they did in Experiment 7). Despite the fact that the reinforcement rate (i.e., the number of pieces that could be moved per unit time) was controlled successfully, the participants did not change their estimates of duration as predicted by BeT when reinforcement rate is varied (i.e., an organisms' perception of time passing is affected by rates of reinforcement). It was assumed in the previous two experiments (and in the current one) that controlling the number of puzzle pieces that can be moved per unit time is a manipulation of the reinforcement rate. As discussed previously, it might be that simply slowing down the speed at which a puzzle piece could be moved did not indicate to the participants that the reinforcement rate had changed and did not, therefore, affect how they estimated duration. Participants continued to work at the jigsaw puzzle by moving the computer mouse around, in some cases, quite erratically. In this next experiment, an attempt was made to signal to the participants that there was a change in the reinforcement rate. The stimuli to signal the change would, it was thought, be analogous to those used in computer usage, with which humans have a history. Thus, it was expected that participants would learn that continual movement of the computer mouse would be ineffective in moving a puzzle piece. It was hoped that the stimulus would signal a change in reinforcement rate and that this would influence the participant's estimates of duration as predicted by BeT.

Method

Participants

Seven participants were recruited as in Experiment 1. They are referred to as P9.1 to P9.7. In this experiment, 2% was credited to their first-year Psychology course.

Apparatus

The apparatus was the same as that used in Experiment 1.

Procedure

The procedure was the same as that used in Experiment 8 except for two differences. The first difference was operational, in that the cursor became inoperative for a set duration after each piece was moved in Conditions 2 and 3. The duration of this inoperative period, termed here the delay, was 5 s in Condition 2 and 10 s Condition 3. Participants could still move the computer mouse around on the mouse pad during these delays but the computer cursor would not move until the interval to be estimated had elapsed. The second difference was visual, in that a 'fade in' delay was also operating in Conditions 2 and 3. The fade-in procedure operated after a piece was moved; at this point, all the other pieces, except the piece just moved, would become transparent and then 'fade in' until becoming fully visible again. The duration of the fade was the same as the programmed delays. So, after a participant moved a piece, simultaneously the computer curser became inoperative and the jigsaw pieces faded in, both for the same delay. This meant that the participant could not move any more puzzle pieces until the delay had timed out. In Condition 1 and in Condition 4, the cursor was always operative and there was no 'fade in' procedure.

As in previous the experiments, participants were escorted into the computer laboratory by the Experimenter. Each participant sat down at a computer and was asked to read the same sheet of instructions used in Experiment 7. Any questions were answered and the Experimenter asked the participant to remove their watch, if they were wearing one, and informed the participant that it would be returned at the end of the experiment. The Experimenter then told the participant they could start when ready. The Experimenter remained in the room. No further communication between the Experimenter and the participant occurred until the end of the session, when the participant was debriefed as to the nature of the experiment.

Results

Figure 9.1 shows the logarithms of the estimates over the actual times at which participants were required to make their estimates, in each condition, plotted against the number of successive estimates made throughout the session. There were nine data points (three in C2, C3 and C4 respectively) for P9.7 that are not shown on the plot due to a scale issue (i.e., the log-ratio was greater than 1 because the ratio was greater than 10/1).

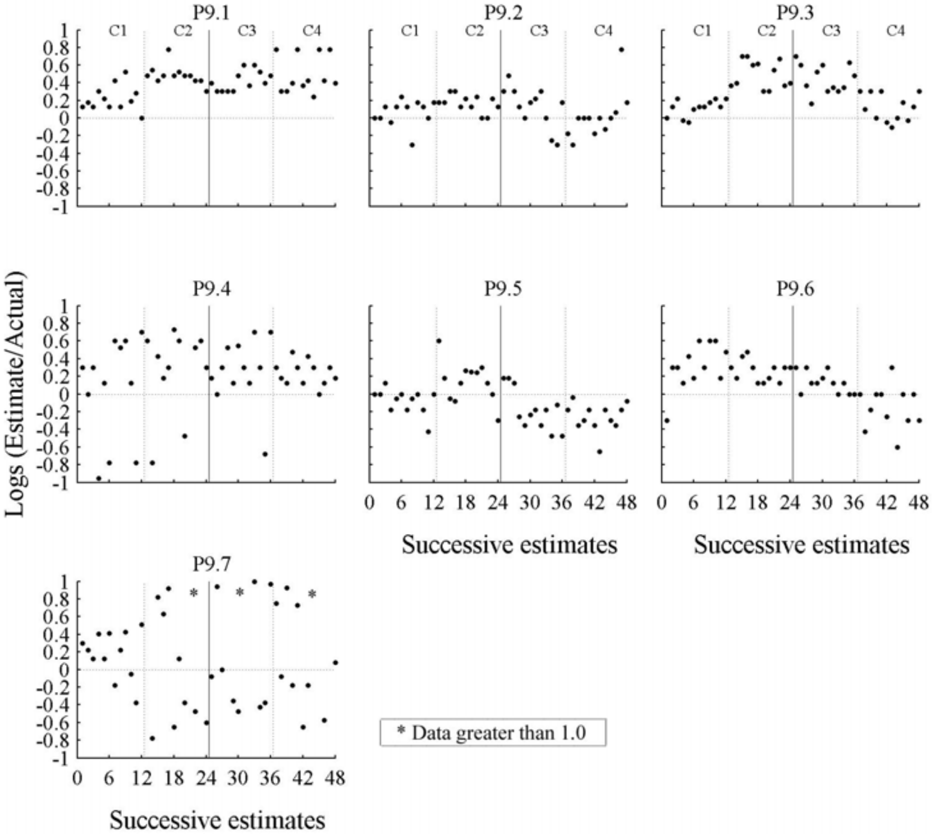

Figure 9.1. Logarithms of the estimates over actual times for each condition, plotted against the successive number of estimates made in the session. C1 & C4: no delay; C2: 5-s delay; C3: 10-s delay.

Figure 9.2 shows the averages of these logarithms for each condition and for each participant. It was expected that participants would estimate time as passing more slowly in C2, where there was a 5-s delay operating, than in C1 and C4 where there was no delay operating, and that they would estimate time as passing even more slowly in C3, where there was a 10-s delay operating, than in C1, C2 or C4. This would be seen by more overestimation (i.e., higher data points in C2 than in C1 and C4) and even more overestimation (i.e., even higher data points) in C3 than in C1, C2 and C4.

Figures 9.1 and 9.2 show that the data did not follow this pattern. Figure 9.2 shows that 6 participants did, on average, overestimate more in C2 than in C1, as predicted. However, in no case was the average (of the logarithms) in C3 higher than that in C2. Figure 9.2 also showed that there were no systematic trends over all conditions and across participants' data.

A two-way repeated measures ANOVA was performed, with the conditions and the time at which estimates were made, as within-subject variables. The ANOVA compared the means of the logarithms of the estimates over the actual times at which participants were required to make their estimates, for the operational and visual manipulation and for the actual times at which estimates were made. There was a main effect of the manipulation upon participants' estimates of duration (F (3, 18) = 3.792, $p < .05$) and the effect size for the manipulation was small (η = .387). Pairwise comparisons showed that the log ratios from Condition 2 (where there was a 5-s delay) were significantly different to those from the other three conditions ($p < .05$). There was a main effect of the times at which estimates were made (F (5, 30) = 3.877, $p < .05$) and the effect size was small (η = .393). Pairwise comparisons showed that the log ratios from the 15-s interval were significantly different to those from the 45-s and 120-s intervals. There was no interaction between the conditions and the times at which estimates were made (F (55, 90) = .868, $p < .05$) and the effect size was small (η = .126). Figure 9.3 shows the logarithms of the estimates over the actual times estimated, together with the 95-percent confidence interval, averaged over all participants' data, plotted against the actual times. The log ratios of participants' estimates of duration tended to decrease as the times at which estimates were made increased. Duration was overestimated more at the 15-s and 30-s intervals than for any of the other intervals.

Figure 9.4 shows the total number of pieces moved in each condition by each participant. In Condition 2, all participants moved fewer pieces than in Condition 1. In

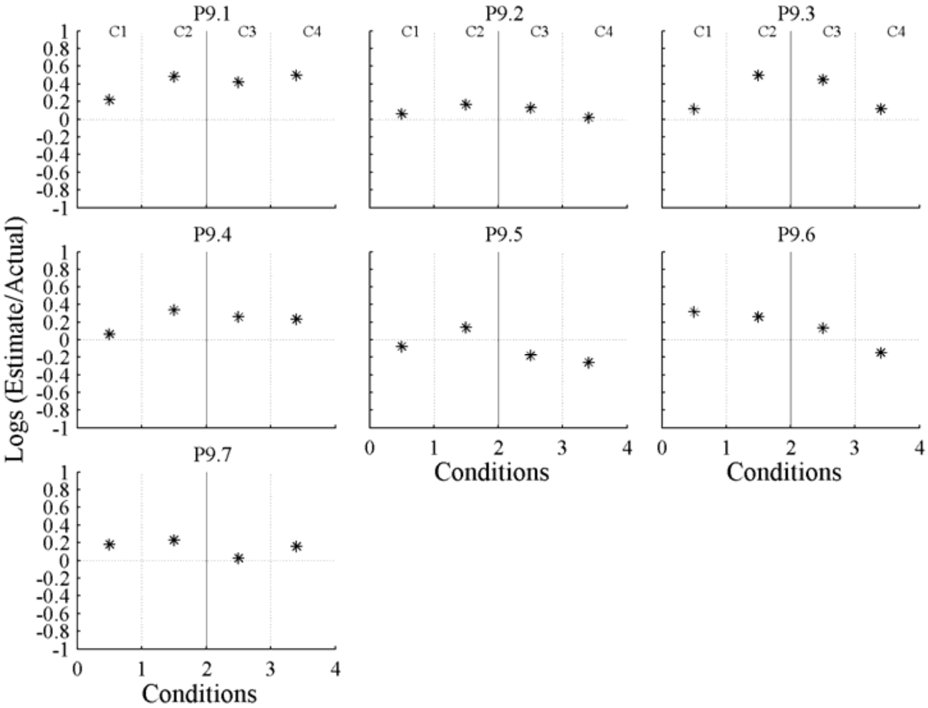

Figure 9.2. Averages of the logarithms of the estimates over the actual times, plotted against each experimental condition. C1 & C4: no delay; C2: 5-s delay; C3: 10-s delay.

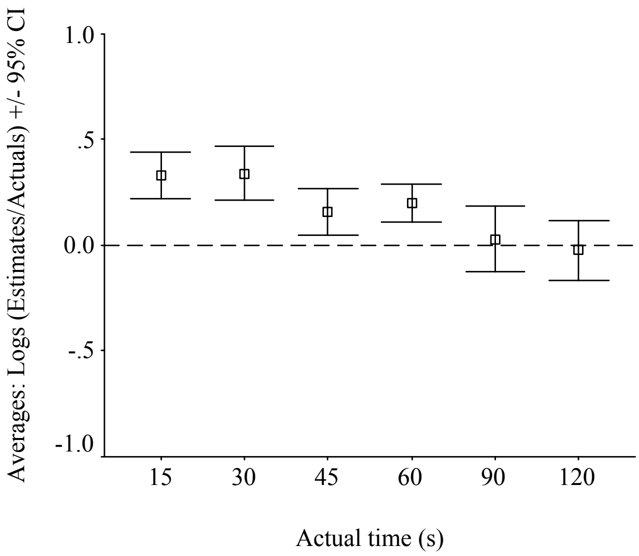

Figure 9.3. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, plotted against the times at which estimates were made.

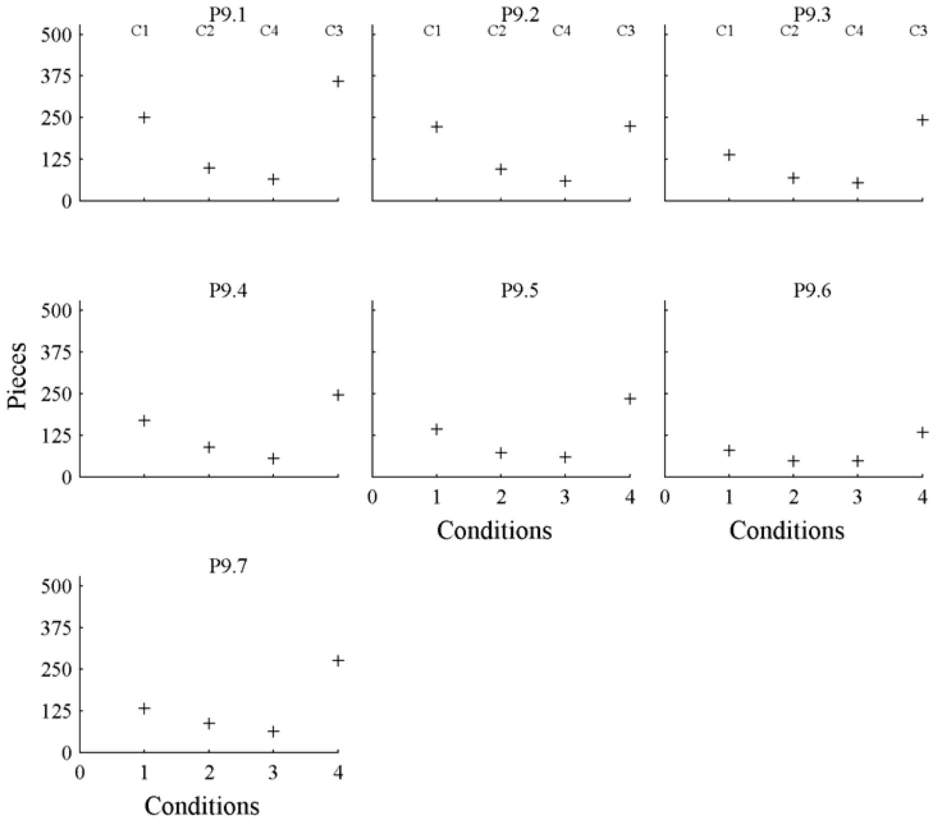

Figure 9.4. Number of pieces moved, plotted against each experimental condition. C1 & C4: no delay; C2: 5-s delay; C3: 10-s delay.

Condition 3, all participants moved fewer pieces than in Condition 2, except P9.6 who moved the same number of pieces in Condition 3 as in Condition 2. In Condition 4, all participants moved more pieces than in any of the previous three conditions. A one-way repeated measures ANOVA was performed, with the number of pieces moved in each condition as the within-subject variable. The ANOVA compared the number of pieces moved for the operational and visual manipulation. There was a main effect of the number of pieces that could be moved (F (3, 24) = 23.296, $p < .05$) and the effect size was large (η = .744). Pairwise comparisons showed that the number of pieces moved in C1 were significantly different from the number moved in C2, C3 and C4. The number of pieces moved in C4 were significantly different from the number moved in C2 and C3 ($p <.05$).

Discussion

In this experiment there was a delay introduced immediately after moving a puzzle piece before another puzzle piece could be moved. The delay was indicated by the puzzle picture 'fading in' and the computer cursor being inoperative. The delay did reduce the number of puzzle pieces that were moved in a session, hence the manipulation resulted in a reduction in the reinforcement rate. The effect of the manipulation was statistically significant for only the 5-s delay and the effect size was small. It is unclear why the effect was not observed in the 10-s delay condition. However, given that the effect size was small for the 5-s delay condition, it is possible that the statistical result obtained here may not be reliable.

Figure 9.4 showed that fewer pieces were moved during the delay conditions than in the non-delay conditions and more pieces were moved in Condition 4 than in Condition 1. It appears that once the delays ended, the participants moved more puzzle pieces in Condition 4 than they had in Condition 1. This trend was also observed in Experiments 7 and 8. It might be possible that the manipulations in these two experiments and in the current one only served to teach participants that a more varied response was needed which would enable them to continue moving pieces, rather than indicating to them that there was a change in the reinforcement rate and consequently, affect their estimates.

There was an effect of the actual times at which estimates were made on the participants' estimates of duration. Figure 9.3 showed that the participants tended to continue underestimating duration more as the actual times at which estimates were made increased. This trend was also observed in Experiments 7 and 8. Duration was also overestimated more at the 15-s interval than for any of the other intervals in this and the previous two experiments. It appears that being asked to make an estimate of duration after a short time results in a greater degree of error than if asked to make an estimate after a longer time (i.e., Figures 7.3, 8.3 and 9.3 showed that duration was estimated more accurately at the 120-s interval than at the 15-s interval). Perhaps having more time to work on a puzzle enables a participant to make a more accurate estimate of the time that has passed. However, if this assumption is correct, it would be expected that there would be less variability, which is not the case. It is unclear why estimates are decreasing as the times at which estimates are made, increase.

The results from this experiment were not conclusive in showing that participants' perception of time passing was reliably affected by signalling to them that a delay was in operation. Beam et al. (1998) investigated how changes in the pacemaker speed of pigeons were affected by signalling changes in the reinforcement rate using strong discriminative stimuli. Increasing the strength of the stimuli was expected to affect the speed of the pigeons' pacemaker. Beams et al.'s (1998) manipulation was successful at affecting the pigeons timing behaviour. Thus, if the stimulus manipulation in this experiment had of been strong, as found by Beam et al. (1998) it would have been expected that there should have been a stronger effect and that the effect would have been across both delay conditions, rather than just one of them. Nevertheless, the significant result found during the 5-s delay condition does suggest that further investigation is required. The following experiment replicated Condition 2, the 5-s delay condition, to test the reliability of the statistical effect found for this condition.

EXPERIMENT 10

In Experiment 9 an attempt was made to signal to the participants when a change in the reinforcement rate was occurring, so their behaviour would, hopefully, come under stimulus control. A significant result was returned for the 5-s delay condition but not the 10-s delay condition. Given this, it could not be concluded that the visual stimulus reliably affected the participants' estimates of duration. The reliability of the result in the previous experiment was assessed in this experiment by replicating the 5-s delay condition.

Method

Participants

Eight participants were recruited as in Experiment 1. They are referred to as P10.1 to P10.8. In this experiment, 2% was credited to their first-year Psychology course.

Apparatus

The apparatus was the same as that used in Experiment 1.

Procedure

The procedure was the same as that used in Experiment 9 except for two differences. The first difference was that the length of the simultaneous 'fade in' and the period during which the cursor was inoperative was 5 s (i.e., a 5-s delay). The second difference was that the order in which the 5-s delay condition was presented was counterbalanced. There were two groups of participants. For the first group, Participants P10.1 to P10.4, the order of the conditions was as follows: Condition 1, no delay; Condition 2, 5-s delay; Condition 3, no delay and Condition 4, 5-s delay. The order was reversed for the second group, Participants P10.5 to P10.8, as follows: Condition 1, 5-s delay; Condition 2, no delay; Condition 3, 5-s delay and Condition 4, no delay. As in the previous experiments, participants were escorted by the Experimenter into the computer laboratory. Each participant sat down at a computer and was asked to read the same sheet of instructions used in Experiment 7. Any questions were answered and the Experimenter asked the participant to remove their watch, if they were wearing one, and informed the participant that it would be returned at the end of the experiment. The Experimenter then told the participant they could start when ready. The Experimenter remained in the room. No further communication between the Experimenter and the participant occurred until the end of the session, when the participant was debriefed as to the aim of the experiment.

Results

Figure 10.1 shows the logarithms of the estimates over the actual times at which participants were required to make their estimates, in each condition, plotted against the number of successive estimates made throughout the session. Figure 10.2 shows the averages of these logarithms for each condition. It was expected that participants would estimate time as passing more slowly in the conditions where there was a 5-s delay operating than in conditions where there was no delay operating. This would be seen by more overestimation (i.e., higher data points) in delay conditions than in the non-delay conditions. Thus, it was predicted that the data in C2 and C4 would be high for P10.1 to P10.4 and the data in C1 and C3 would be high for P10.5 to P10.8. Neither of these patterns was found for any participant. The log ratios for P10.1, P10.3 and P10.4 show that these participants did not estimate duration more in C2 (a 5-s delay condition) compared to C1 (a non-delay condition) as expected, whereas P10.2 did. P10.8 estimated duration in C1 (a 5-s delay condition) more than in C2 (a non-delay condition). Figure 10.2 also shows that the participants did not consistently estimate duration as the session progressed.

A two-way repeated measures ANOVA was performed, with condition and the time at which estimates were made, as within-subject variables and the order in which the conditions were presented as the between-subjects variable. The ANOVA compared the means of the logarithms of the estimates over the actual times at which participants were required to make their estimates, for the operational and visual manipulation and for the actual times at which estimates were made. There was no main effect of the manipulation (i.e., delay) upon participants' estimates of duration (F (1, 6) = .521, p > .05) and the effect size for the manipulation was small (η = .080). There was however, a main effect of the times at which estimates were made (F (5, 30) = 6.517, p < .05) and the effect size was medium (η = .521). Pairwise comparisons showed that the log ratios from the 15-s interval were significantly different to those from the other intervals (p <.05) and those from the 45-s interval were significantly different to the log ratios from the 60-s and 90-s intervals

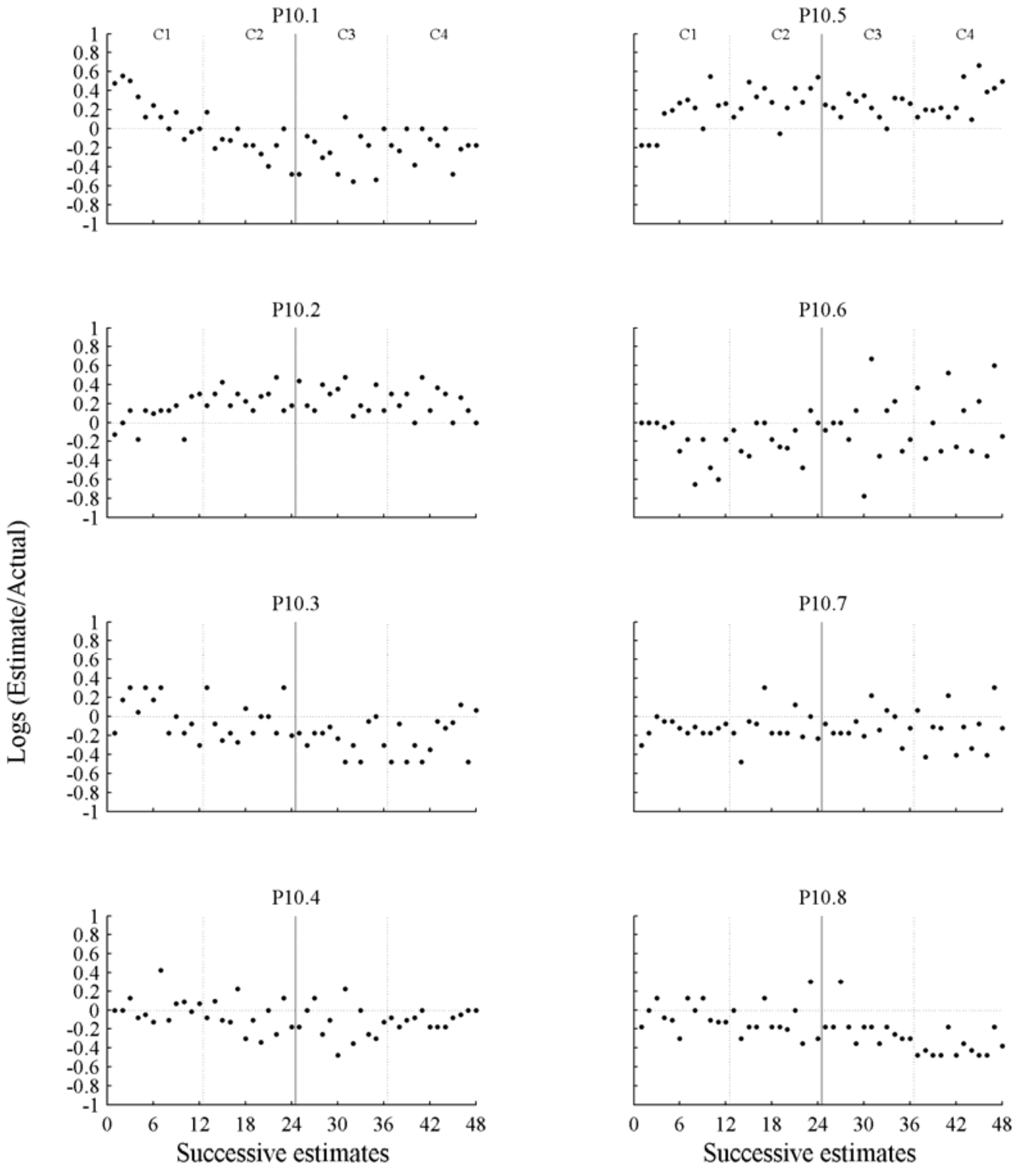

Figure 10.1. Logarithms of the estimates over the actual times for each condition, plotted against the successive number of estimates made in the session.
P10.1-P10.4: C1 & C3: no delay; C2 & C4: 5-s delay.
P10.5-P10.8: C1 & C3: 5-s delay; C2 & C4: no delay.

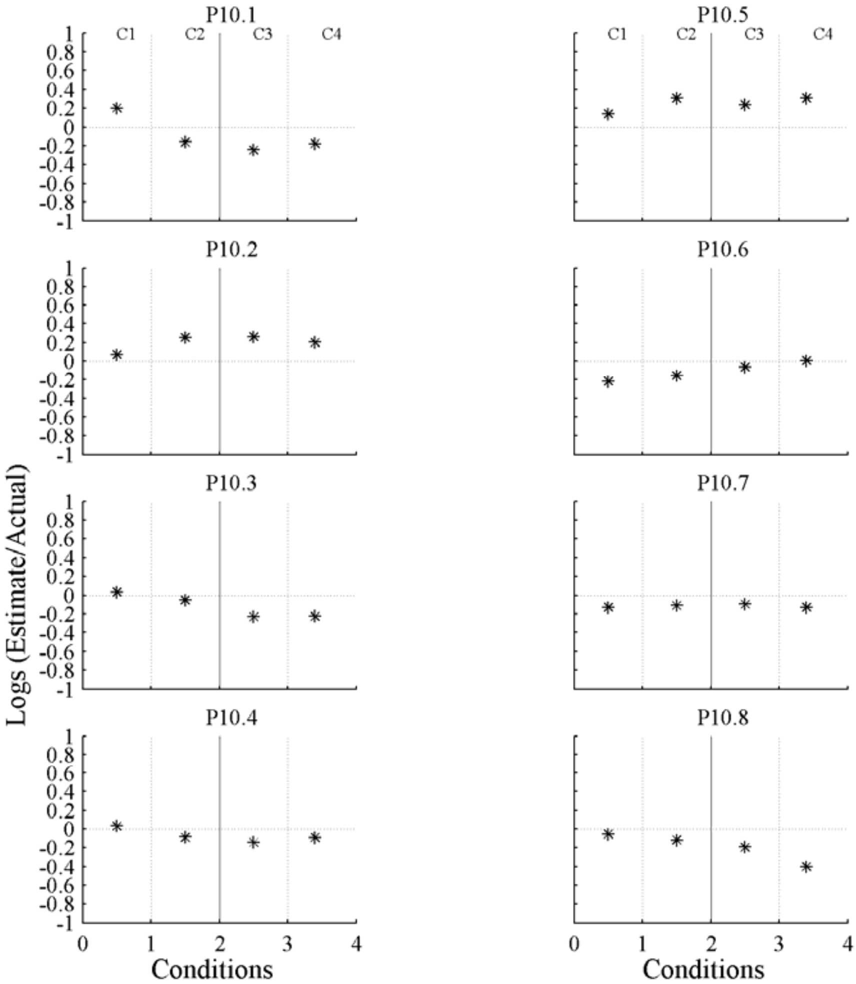

Figure 10.2. Averages of the logarithms of the estimates over the actual times, plotted against each experimental condition. P10.1-P10.4: C1 & C3: no delay; C2 & C4: 5-s delay. P10.5-P10.8: C1 & C3: 5-s delay; C2 & C4: no delay.

(p <.05). There was no between-treatments effect of presentation order (F (1, 6) = .024, p > .05) and the effect size was small (η = .004). There was an interaction effect of the delay and the times at which estimates were made (F (5, 30) = 3.401, p < .05). The effect size for the interaction was small (η = .362). The analyses also showed that there were no significant interactions between any other combinations of delay, presentation order and the times at which estimates were made, at the .05 alpha level.

Figure 10.3 shows the logarithms of the estimates over the actual times estimated, together with the 95-percent confidence interval, averaged over all participants' data, plotted against the actual times. The log ratios of participants' estimates of duration tended to decrease as the times at which estimates were made increased. Duration was overestimated more at the 15-s interval than for any of the other intervals.

Figure 10.4 shows the total number of pieces moved in each condition by each participant. P10.1 to P10.4 moved fewer pieces in Conditions 2 and 4, the 5-s delay conditions, compared to Conditions 1 and 3, where there were no delays operating. The conditions were presented in the reverse order for P10.5 through P10.8, compared to the first four participants. P10.5 to P10.8 moved fewer pieces in Conditions 1 and 3, the 5-s delay conditions, compared to Conditions 2 and 4, where there were no delays operating. A one-way repeated measures ANOVA was performed, with the number of pieces moved in each condition as the within-subject variable and the order in which the conditions were presented as the between-subjects variable. The ANOVA compared the number of pieces moved for the operational and visual manipulation. There was a main effect of the number of pieces that could be moved (F (3, 18) = 4.452, p < .05) and the effect size was small (η = .426). Pairwise comparisons showed that the numbers of pieces moved in Condition 1 were significantly different from the numbers moved in Condition 3 (p <.05). The numbers of pieces moved in Condition 2 were significantly different from the numbers moved in Conditions 3 and 4 (p <.05). There was no between-treatments effect of the presentation order (F (1, 6) = .710, p > .05) and the effect size was small (η = .106). There was an interaction effect between the numbers of pieces moved and the order in which the conditions were presented (F (3, 18) = 45.664, p < .05). The effect size for the interaction was large (η = .884).

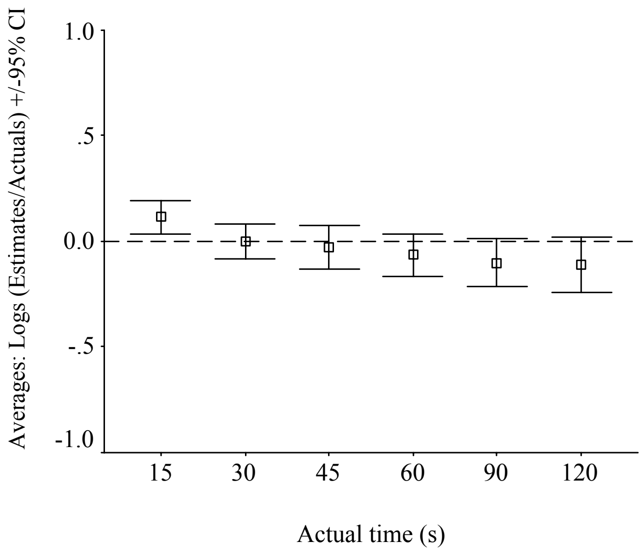

Figure 10.3. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, plotted against the times at which estimates were made.

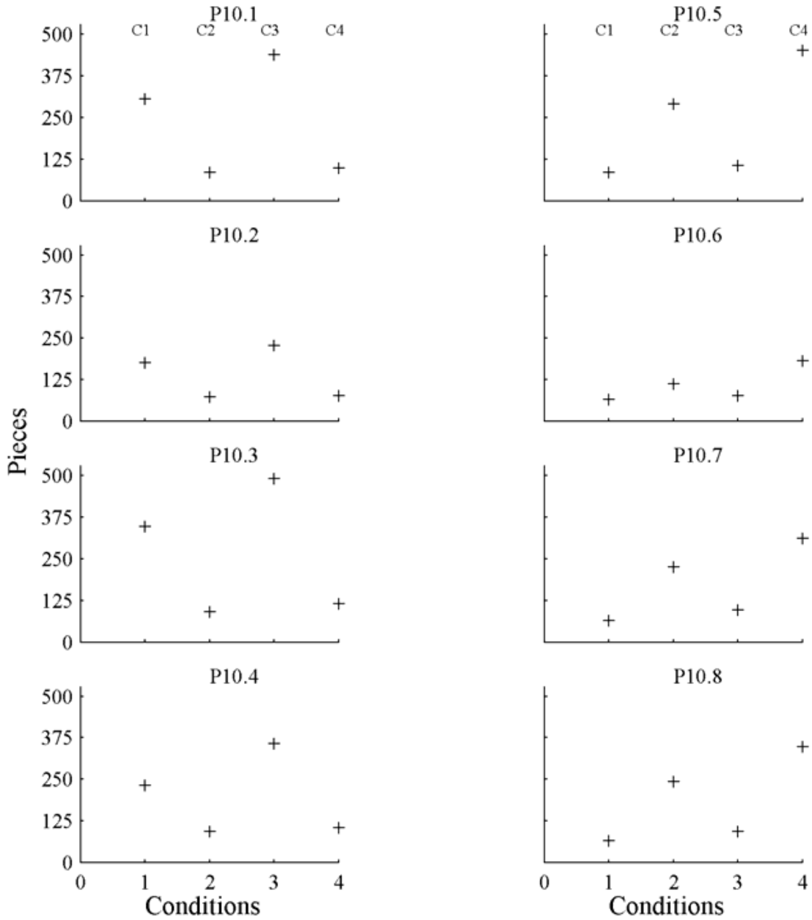

Figure 10.4. Number of pieces moved, plotted against each experimental condition. P10.1-P10.4: C1 & C3: no delay; C2 & C4: 5-s delay. P10.5-P10.8: C1 & C3: 5-s delay; C2 & C4: no delay.

Discussion

This experiment tested the reliability of the effect found in Experiment 9. The effect was not reproduced, as the changes in the reinforcement rate did not result in changes in how the participants estimated duration. Figure 10.1 showed that there was variation in participants' estimates throughout the experiment. The order in which the conditions were presented was counterbalanced to control for order effects but none were found. There was an interaction between the number of pieces moved and the order in which the conditions were presented. This effect suggests an interdependence between pieces moved and condition. Thus, more pieces would have been moved in a non-delay condition (or fewer pieces moved in a 5-s delay condition) irrespective of the order in which the conditions could have been presented.

Figure 10.2 showed that fewer pieces were moved in the delay conditions compared to the non-delay conditions. This suggests that manipulating the delay influenced the number of pieces that could be moved, resulting in control of the reinforcement rate. However, participants moved more pieces in the second non-intervention condition than in the first non-intervention condition. This suggests that the participants kept on working at the jigsaw, increasing the number of pieces they moved as they continued trying to complete the puzzle. In Experiment 9, participants also moved more pieces in the second non-intervention condition than in the first non-intervention condition. It may be possible that manipulation of the stimuli in this and in the previous experiment may only serve to suggest to participants that they need to vary how they respond, rather than affecting how they estimate duration.

BeT (Killeen & Fetterman, 1988, 1993) predicts that the reinforcement rate affects an organisms' perception of time passing. In the present series of experiments it was assumed that moving puzzle pieces was a reinforcer and thus, allowed for the manipulation of the reinforcement rate (i.e., moving more puzzle pieces in a set time should be equivalent to gaining a higher rate of reinforcement and moving fewer pieces should be equivalent to a drop in the reinforcement rate). In Experiment 7, there was evidence that the reinforcement rate was not effectively controlled or manipulated. Even when there was control of the reinforcement rate in the current experiment and in Experiments 8 and 9, manipulation of the number of puzzle pieces had no effect upon how long participants' estimated the interval to be. The results from this series of experiments brings into question the assumption that moving puzzle pieces per unit time is a way to successfully manipulate the reinforcement rate, affecting how participants estimate duration. This suggests that further investigation is needed into reassessing this assumption.

The majority of BeT experimental studies have used animals as subjects and it appears that BeT predicts animals' timing behaviour, in that animals' timing behaviour comes under control of the reinforcement rate. Previous studies with humans also support the predictions of BeT (Fetterman et al., 1993; Fetterman & Killeen, 1992). However, this present series of experiments with humans failed to obtain results as predicted by BeT. As mentioned above, moving puzzle pieces per unit time may not be a successful way of manipulating the reinforcement rate. However, it may also be possible (if we assume that that moving puzzle pieces per unit time is a successful way of manipulating the reinforcement rate) that the attempts made to influence how participants estimated duration in this experimental series may not have indicated to participants that there had been a change in the reinforcement rate. In Experiment 9 and consequently in the current experiment, this idea was tested and an attempt was made to signal to participants that there was a change in the reinforcement rate by using stimuli, it was hoped, that were analogous to those in computer usage with which humans have a history. Although these changes did have an effect on the number of pieces that were moved, they did not affect estimates of duration. It may be possible that a more extreme manipulation is required, one that will indicate to participants that there has been a change in the reinforcement rate. The next experiment was designed to test this.

EXPERIMENT 11

In Experiment 9 an attempt was made to signal to the participants that changes in the reinforcement rate were occurring by introducing a delay, where the picture puzzle 'faded in' and the computer cursor was inoperative. This was partially successful in that the 5-s delay intervention condition returned a statistically significant result, although the effect size was small. Thus, in Experiment 10, this condition was replicated. However, the statistically significant finding was not replicated. Having failed to obtain control through previous manipulations of the reinforcement rate, it was decided to test the most extreme case, where the task was completely absent. The rate was reduced to zero by removing the puzzle altogether. If reinforcement was provided by having access to being able to do the jigsaw by successfully moving pieces this would make the rate zero when there was no puzzle. It was hoped that this would affect participants' estimates of duration. Thus, in this next experiment, manipulation of the reinforcement rate occurred across the experimental session by providing periods in which the puzzle could be done and periods in which it was removed.

Method

Participants

Eight participants were recruited as in Experiment 1. They are referred to as P11.1 to P11.8.

Apparatus

The apparatus was the same as that used in Experiment 1.

Procedure

The procedure was similar to that used in Experiment 10 except the simultaneous 5-s 'fade in' and inoperative cursor conditions that were operating in Experiment 10 were not used and the number of conditions within the session was increased from four to eight.

The order in which the conditions were presented for Participants P11.1 to P11.4 was as follows: Jigsaw-Blank-Jigsaw-Blank-Jigsaw-Blank-Jigsaw-Blank. For Participants P11.5 to P11.8, the order of presentation was reversed. In the jigsaw condition, participants could do the puzzle without any programmed restrictions or manipulations. In the blank screen condition, the entire computer screen went black and the jigsaw was not visible at all. During this period, participants had no access to being able to do the jigsaw puzzle. Participants had to sit and wait and were required to make an estimate of the time interval when the computer prompted them to do so. When the blank condition timed out and the jigsaw reappeared on the screen, the participants were again given access to moving puzzle pieces. The times at which participants were prompted by the computer to make their estimates of duration are given in Table 11.1. The session was divided into eight 6-min conditions. Initially, participants were asked to estimate the time that had passed since they began the experiment, and from then after, were asked to estimate the time that had passed since their previous estimate. Six estimates were made within each condition, with 48 estimates being made in total.

As in the previous experiments, participants were escorted into the computer laboratory by the Experimenter. Each participant sat down at a computer and was asked to read the sheet of instructions. The instructions were as follows:

Introduction:

This experiment involves working with jigsaw puzzles where you move pieces around to complete a picture. You will be required to estimate the time you think you have been working on the puzzle. Please read the steps below to familiarise yourself with the experimental procedure.

Procedure:

In the experiment, a puzzle with a number of squares will be displayed on the computer screen. Each of these squares is part of a picture you will see in the top left hand corner of the computer screen when you move the pointer over the preview button directly to the right of the target picture. Your task is to use the mouse to move the pointer over a square and depress the left mouse button to drag that square to a new location. You can repeat this until you have completed the puzzle. At other times, the screen will appear blank.

Throughout the experiment a box will appear in the centre of the computer screen asking you to estimate how long you think you have been doing the puzzle or how long you think the blank period was. You may write your estimate in terms of minutes, seconds or both on the flip pad provided. Once you have written down your estimate on the flip pad turn the page over in preparation for writing down the next estimate. Now use the mouse to move the pointer over the 'Continue' button situated below the estimation instructions and depress the left mouse button to start the puzzle again.

Table 11.1

The times at which estimates were made for each 6-minute condition.

Times at which estimates were made (in seconds)

6-min conditions

1	2	3	4	5	6	7	8
60	15	30	45	60	15	30	45
30	90	120	120	30	90	120	120
15	30	45	30	15	30	45	30
90	45	60	90	90	45	60	90
45	120	15	15	45	120	15	15
120	60	90	60	120	60	90	60

> If you have any questions please ask them now. You may start the experiment by using the mouse to move the pointer over the 'Start' button and depress the left mouse button to begin.

Any questions were answered and the Experimenter asked the participant to remove their watch, if they were wearing one, and informed the participant that it would be returned at the end of the experiment. The Experimenter then told the participant they could start when ready. The Experimenter remained in the room. No further communication between the Experimenter and the participant occurred until the end of the session, when the participant was debriefed as to the nature of the experiment.

Results

Figure 11.1 shows the logarithms of the estimates over the actual times at which participants were required to make their estimates, in each condition, plotted against the number of successive estimates made throughout the session. P11.1 to P11.4 started the session with the jigsaw condition first, whereas P11.5 to P11.8 started the session with the blank condition first. Figure 11.2 shows the averages of these logarithms for each condition and each participant. It was expected that participants would overestimate duration more in the blank conditions than in the jigsaw conditions. This would be seen by higher data points in the blank conditions than in the jigsaw conditions. The data in Figures 11.1 and 11.2 show that this was generally the case. Figure 11.2 shows that P11.1, P11.2, P11.3, P11.5 and P11.8 overestimated duration more in the blank than in the jigsaw conditions as expected.

A two-way repeated measures ANOVA was performed, with task complexity and the time at which estimates were made, as within-subject variables and the order in which the task was presented as the between-subject variable. The ANOVA compared the means of the logarithms of the estimates over the actual times at which participants were required to make their estimates, for both the jigsaw and blank conditions, and for the actual times at which estimates were made. It was found that there was a significant effect of the condition manipulation upon participants' estimates of duration (F (1, 6) = 10.035, p <.05) and the effect size was medium (η = .626). There was no between-treatments effect of presentation order (F (1, 6) = .138, p >.05) and the effect size was small (η = .187). There was no significant interaction between condition manipulation and presentation order

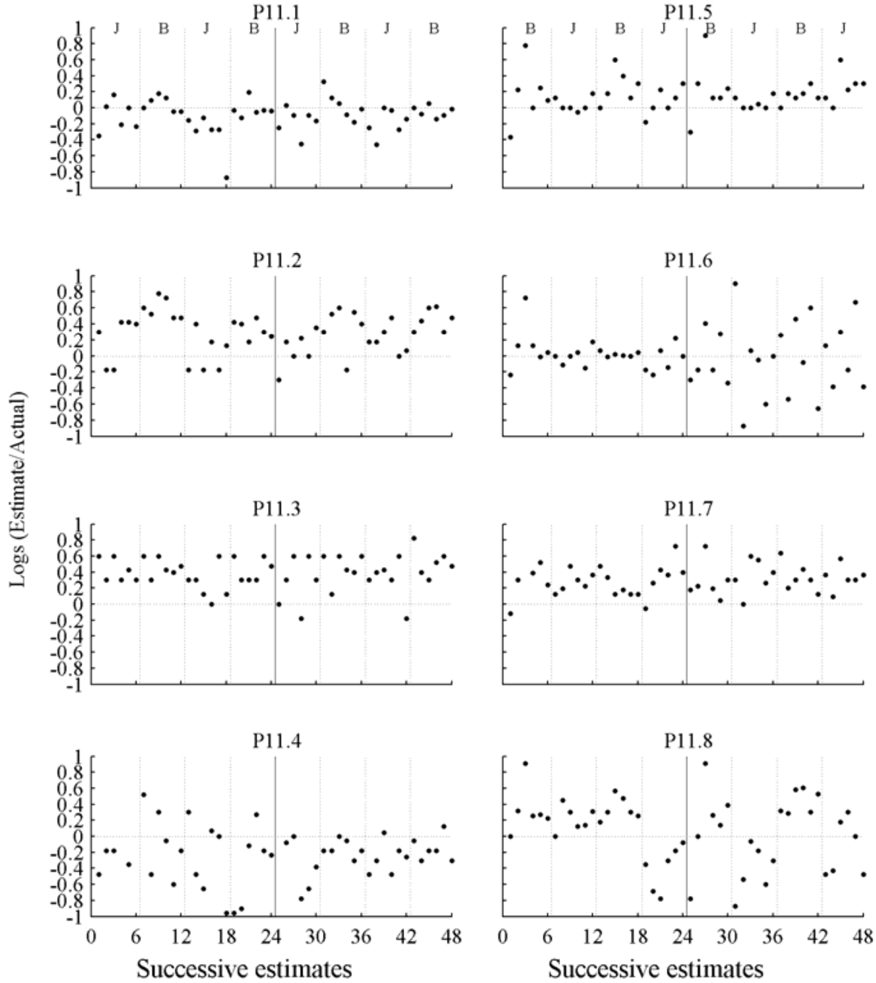

Figure 11.1. Logarithms of the estimates over the actual times for each condition, plotted against the successive number of estimates made in the session. B = Blank; J = Jigsaw.

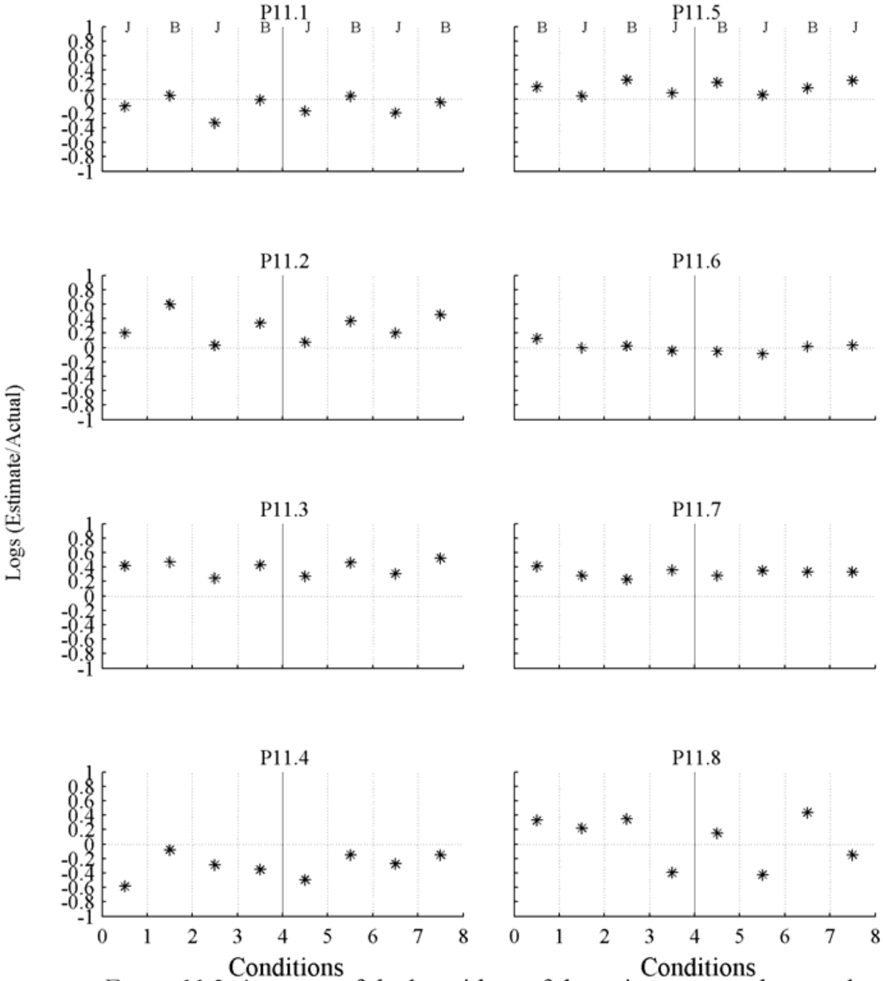

Figure 11.2. Averages of the logarithms of the estimates over the actual times, plotted against each experimental condition. B = Blank; J = Jigsaw.

(F (1, 6) = .308 p >.05). There was a significant main effect of the times at which estimates were made (F (5, 30) = 5.397, p < .05) and the effect size was medium (η = .474). Pairwise comparisons showed that the log ratios from the 15-s interval were significantly different to those from the 45-s, 60-s and 120-s intervals (p <.05). There was also a significant difference between the log ratios from after the 30-s interval and those from the 60-s interval (p <.05). There was no significant difference between the log ratios from any of the other time intervals.

The mean data from the jigsaw and blank conditions are given in Figure 11.3. This shows the means of the logarithms of the estimates over the actual times, together with the 95-percent confidence interval, from all data from the jigsaw condition and all data from the blank condition. Figure 11.3 shows that, on average, intervals during the blank condition were overestimated, whereas, on average, intervals during the jigsaw conditions were estimated accurately. The logarithm ratio averages, expressed as a percentage of participants' under- or over-estimations of the actual time showed that the estimates made during the blank condition were 58 percent bigger than the actual times, whereas during the jigsaw condition, the estimates approximated the actual times.

Figure 11.4 shows the averages of the logarithms of the estimates over the actual times, together with the 95-percent confidence interval, plotted against the times at which estimates were made. Participants overestimated most after 15-s intervals and the degree of overestimation decreased as the intervals increased. Estimates were, on average, accurate after the 120-s interval.

The averages of the logarithms of the estimates over the actual times, together with the 95-percent confidence interval, plotted against the times at which estimates were made for the jigsaw and blank conditions are shown in Figures 11.5 and 11.6 respectively. The same trend observed in Figure 11.4 can be seen in Figures 11.5 and 11.6. The log ratios during both the jigsaw and blank conditions decreased as the times at which estimates were to be made increased. Figure 11.5 shows that during the jigsaw condition, more overestimation occurred when the times at which estimates were made were shorter than when they were longer. However, during the blank condition, Figure 11.6 shows that overestimation occurred at all the times when estimates were made.

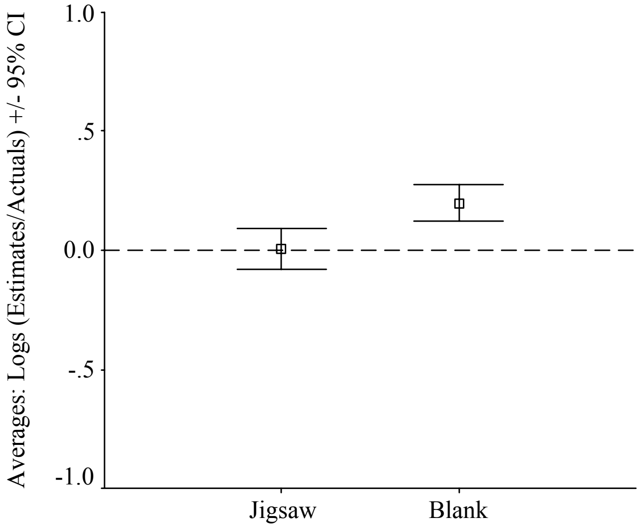

Figure 11.3. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, plotted against the jigsaw and blank conditions.

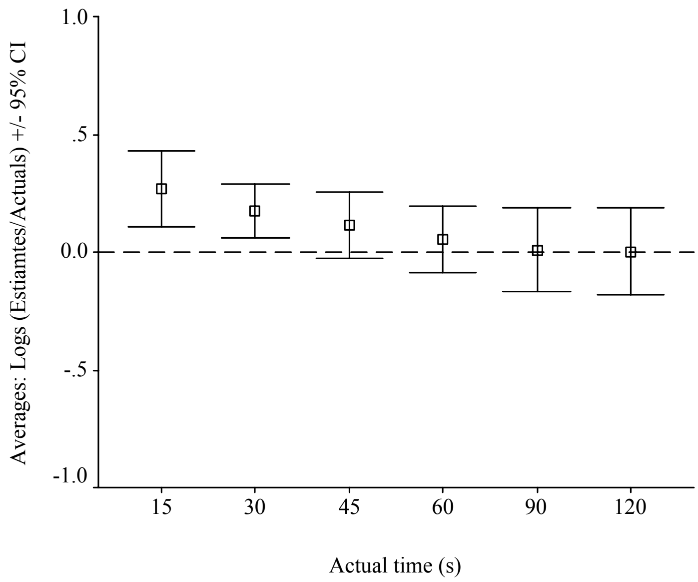

Figure 11.4. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, plotted against the times at which estimates were made.

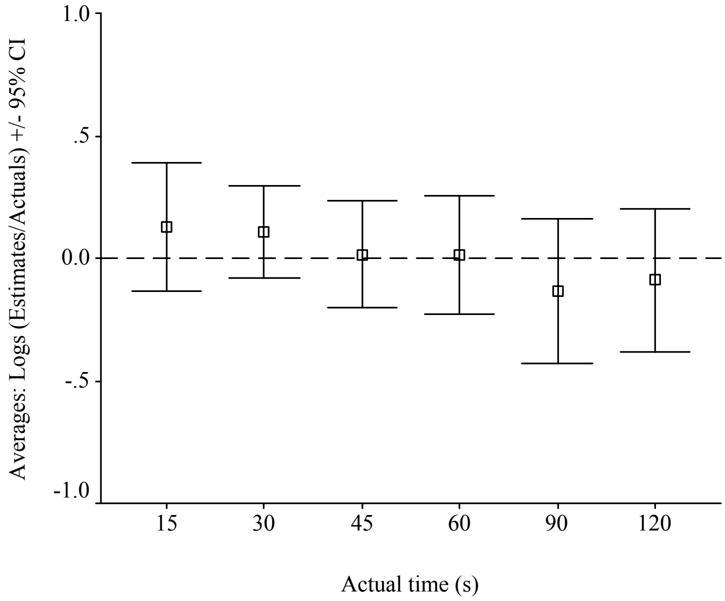

Figure 11.5. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, plotted against the times at which estimates were made, for the jigsaw conditions.

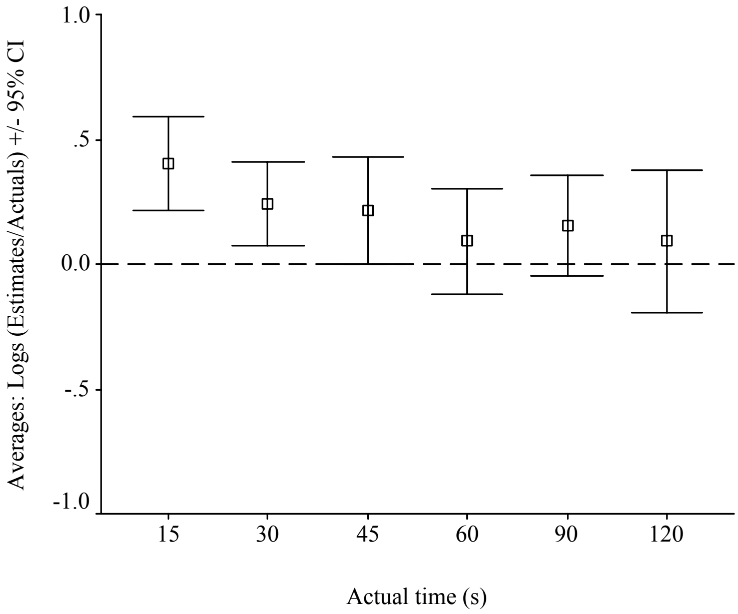

Figure 11.6. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, plotted against the times at which estimates were made, for the blank conditions.

Discussion

In this experiment, an attempt was made to indicate to the participants there was a change in reinforcement rate by removing their access to being able to work on the jigsaw puzzle during the blank conditions, irrespective of the interval being estimated. This resulted in a statistically significant effect and participants estimated duration as passing more slowly in the blank conditions than in the jigsaw conditions. Figure 11.2 showed that in the blank conditions, the log ratios of the estimates over the actual times were higher than the log ratios of the estimates over the actual times in the jigsaw conditions, irrespective of whether the blank condition preceded the jigsaw condition or visa-versa. These results support BeT, where Killeen and Fetterman (1988, 1993) argued that estimates of duration are overestimated when there is a reduction in the reinforcement rate. Manipulation of the reinforcement rate across the session affected participants' estimates of duration in the same way that animal timing behaviour is affected as predicted by BeT.

Morgan et al. (1993) found that pigeons estimated time as passing faster upon returning to baseline after being exposed to lower rates of reinforcement than in the baseline condition. In this experiment, Figure 11.2 shows that participants, generally estimated duration as passing faster, repeatedly, in each jigsaw condition than in each blank condition. The availability of reinforcement, or lack of it during the blank conditions, appears to have affected human estimates of duration, in the same way as Morgan et al. (1993) have shown it to affect pigeons' estimates.

The reinforcement rate in this experiment was reduced to zero by making the screen go blank. Thus, participants' access to the jigsaw was removed as they could no longer see it. In Experiments 7 to 10, where there was no significant effect on estimates of duration, participants' access to the jigsaw had not been removed but they were unable to move puzzle pieces. In Experiments 7 to 10, participants had access to the jigsaw puzzle in all conditions, whereas in this experiment access was removed in certain conditions. It might be possible that having access to the jigsaw puzzle was, in spite of not being able to move the pieces, affecting participants' estimates of duration. The blank condition had been effective in producing overestimates of duration. However, it is unclear what accounted for this. Unfortunately, in the blank condition the opportunity to move puzzle pieces is removed (i.e., reinforcement is zero) and the jigsaw is not available to participants. This situation confounds reinforcement rate with access, making it difficult to determine which factor is responsible for the overestimations. The next experiment explored this possibility to determine whether there was an effect of the access to the jigsaw puzzle upon participants' estimates of duration.

EXPERIMENT 12

In Experiment 11, participants' estimates of duration were affected when all access to the jigsaw was removed (i.e., the blank condition). Duration was overestimated more in the blank conditions than in the jigsaw conditions. However, there could be a confound between there being no arranged reinforcement during the blank condition and the effect of participants having no access to the jigsaw puzzle. It is unclear why participants overestimated duration in the blank conditions in Experiment 11. Was it that they did not have access to the jigsaw puzzle at all or because they did not have access to moving a puzzle piece successfully?

In this experiment there were eight conditions and the manipulation consisted of limiting participants' access to being able to do the jigsaw puzzle, whilst simultaneously controlling the reinforcement rate (i.e., the number of pieces that could be moved). In two conditions (the standard conditions) participants were able to work at doing the jigsaw puzzle freely and it remained visible at all times. During the remaining six intervention conditions, participants had limited access to the jigsaw puzzle. The puzzle was presented (i.e., they could see it) and they had an opportunity to move a puzzle piece. However, once a piece was moved, they had to wait for one of three delays (i.e., 20 s, 60 s and 120 s, depending on the condition in effect) during which the screen was blank. Once this delay timed out, the jigsaw reappeared and they had another opportunity to move a puzzle piece. The reinforcement rate was controlled by the three delays (i.e., with a 20-s delay, participants were presented with six times as many opportunities to move a puzzle piece than with a 120-s delay).

It was expected that if participants' estimates were affected by the reinforcement rate or by the removal of the puzzle, then there should be a difference in the estimates of duration from different conditions (i.e., the three delay conditions and the standard condition). Differences in each of the delay conditions would suggest an effect of the reinforcement rate upon duration estimates, whereas no differences would suggest an effect of limiting access to the puzzle.

Method

Participants

Sixteen participants were recruited as in Experiment 1. They are referred to as P12.1 to P12.16.

Apparatus

The apparatus was the same as that used in Experiment 1.

Procedure

The procedure was similar to that used in Experiment 11 except for the following changes. The jigsaw puzzle was presented in the first and in the last experimental conditions, and participants were able to work freely on the jigsaw puzzle. The jigsaw puzzle was also presented in the second to the seventh experimental conditions but participants were not able to work freely at doing the jigsaw puzzle (i.e., continuously moving more than one puzzle piece). During these conditions, the re-presentation of the jigsaw puzzle was delayed after each move. At the beginning of each of these conditions participants were presented with an opportunity to move a puzzle piece. When a puzzle piece was moved, the screen went blank. The screen remained blank for the length of the delay in operation. The delays were 20 s, 60 s and 120 s cross conditions 2 to 7. Once the delay timed out, the jigsaw was again presented so a piece could be moved. Once the participant moved a puzzle piece the screen went blank once more. With a longer delay, a fewer number of puzzle pieces could be moved, hence manipulating the reinforcement rate within conditions.

The order in which the delays were presented, for all participants and irrespective of whether a standard or a delay condition was operating, was as follows: standard (no delay) (C1), 20-s delay (C2), 60-s delay (C3), 120-s delay (C4), 120-s delay (C5), 60-s delay (C6), 20-s delay (C7) and standard (C8). The times at which participants estimated duration were the same as in Experiment 11 (i.e., 15 s, 30 s, 45 s, 60 s, 90 s and 120 s). These times were randomised thus, where a 120-s delay was operating, participants would only be able to move a jigsaw piece every 120 s, but could make several estimates during the delay period, as most of the times at which the computer prompted participants to make an estimate were less than 120 s.

As in previous experiments, the Experimenter escorted participants into the computer laboratory, where the same set of instructions used in Experiment 11 were read and watches were removed. The Experimenter then told each participant they could start when ready. The Experimenter remained in the room. No further communication between the Experimenter and the participant occurred until the end of the session, when the participant was debriefed as to the nature of the experiment.

Results

Figures 12.1 and 12.2 show the logarithms of the estimates over the actual times at which participants were required to make their estimates, in each condition, plotted against the successive number of estimates made throughout the session. Figures 12.3 and 12.4 show the averages of these logarithms for each condition and each participant. If access to the puzzle affected estimates then it would be expected that duration would be overestimated more than in the delay conditions (C2 to C7) than in the standard conditions (C1 and C8). This would be seen as higher data points in the delay conditions than in the standard conditions. Also, if the rate at which puzzle pieces could be moved had a differential affect then it would be expected that in the delay conditions duration would be overestimated more when there were longer delays than when there were shorter delays. This would be seen as higher data points when there was a 120-s delay (C4 and C5) than when there were 60-s and 20-s delays, and higher data points when there was a 60-s delay (C3 and C6) than when there was a 20-s delay (C2 and C7).

Figures 12.1, 12.2, 12.3 and 12.4 show that the data did not follow this latter pattern. The log ratios of the estimates to actual times in the first three conditions for P12.1, P12.3, P12.5, P12.7, P12.9 and P12.14 increased as expected (i.e., the data points in C2 were higher than in C1 and those in C3 were higher than those in C2). However, the remaining log ratios show that the estimates for these participants did not consistently follow the expected pattern (i.e., data points highest in C4 and C5; data points higher in C6 than in C7, and data points higher in C7 than in C8).

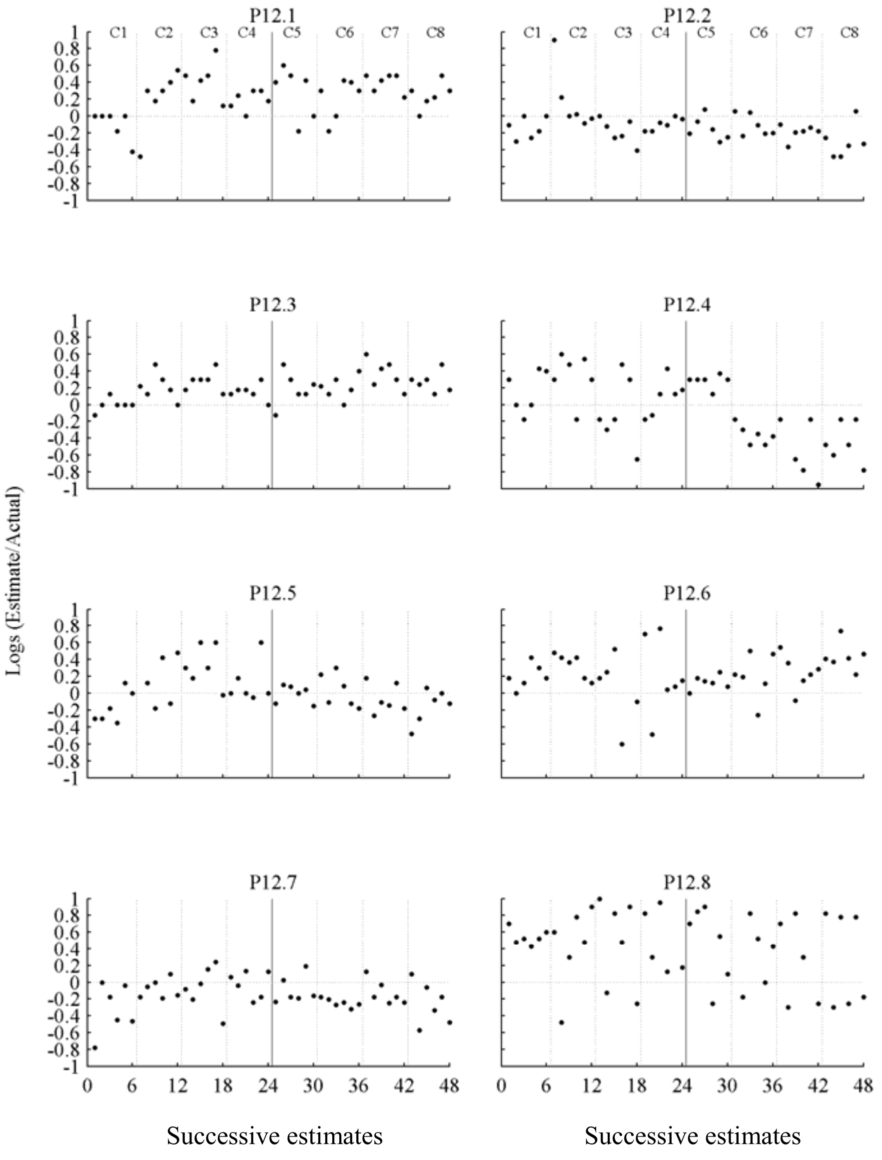

Figure 12.1. Logarithms of the estimates over the actual times for each condition, plotted against the successive number of estimates made in the session. P12.1-P12.8. C1: Standard; C2: 20-s delay; C3: 60-s delay; C4: 120-s delay; C5: 120-s delay; C6: 60-s delay; C7: 20-s delay; C8: Standard.

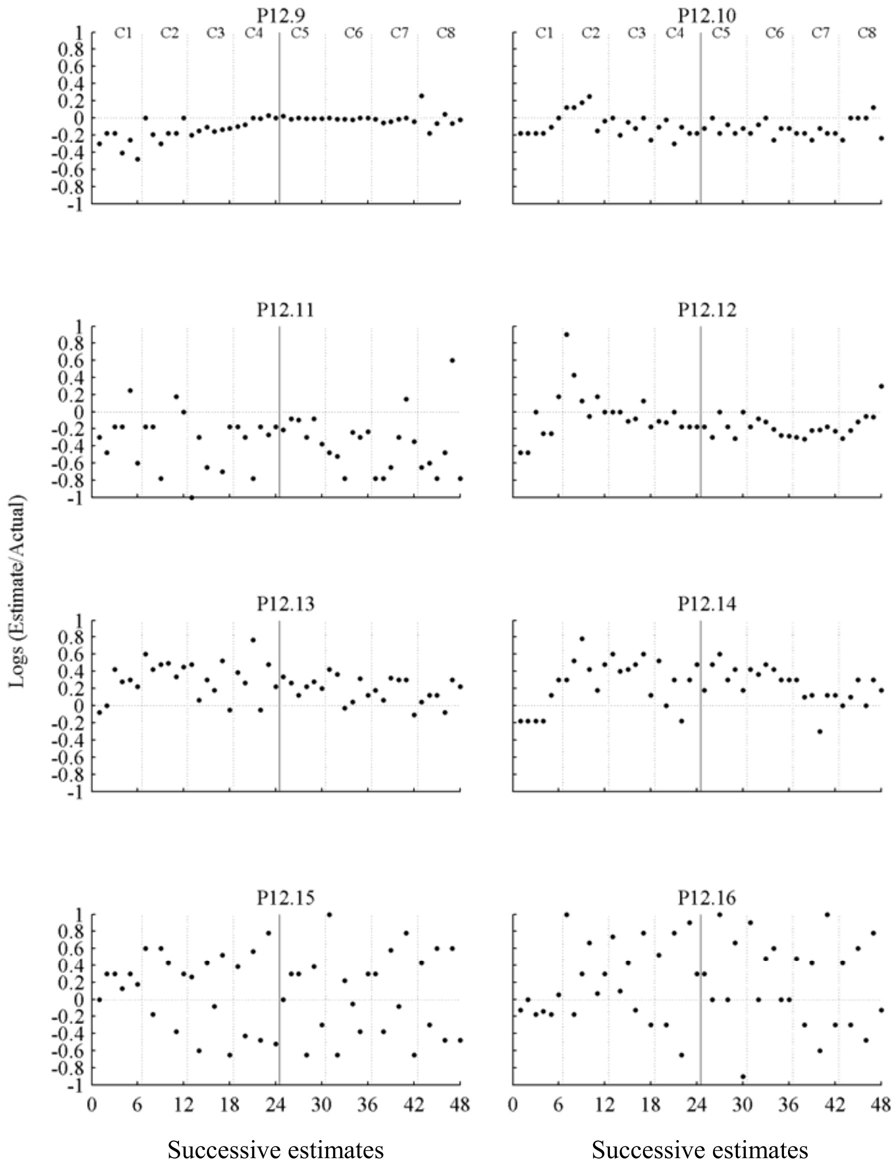

Figure 12.2. Logarithms of the estimates over the actual times for each condition, plotted against the successive number of estimates made in the session. P12.9-P12.16. C1: Standard; C2: 20-s delay; C3: 60-s delay; C4: 120-s delay; C5: 120-s delay; C6: 60-s delay; C7: 20-s delay; C8: Standard.

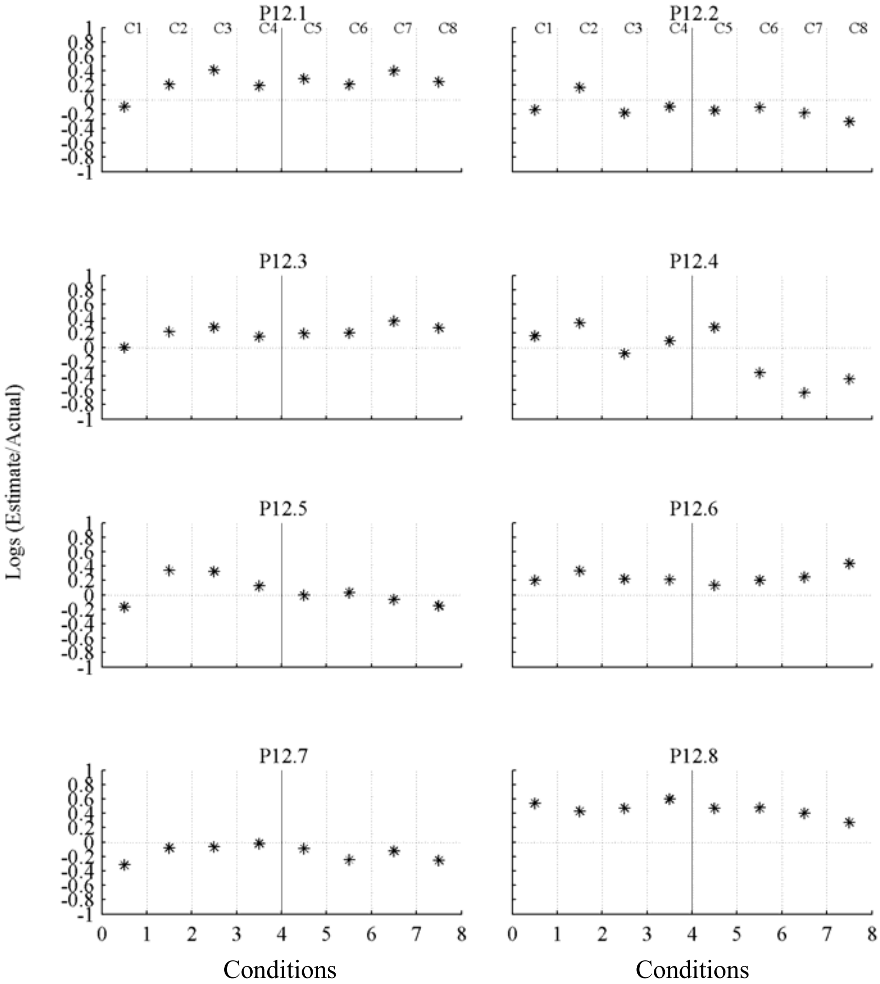

Figure 12.3. Averages of the logarithms of the estimates over the actual times, plotted against each experimental condition. P12.1-P12.8.
C1: Standard; C2: 20-s delay; C3: 60-s delay; C4: 120-s delay; C5: 120-s delay; C6: 60-s delay; C7: 20-s delay; C8: Standard.

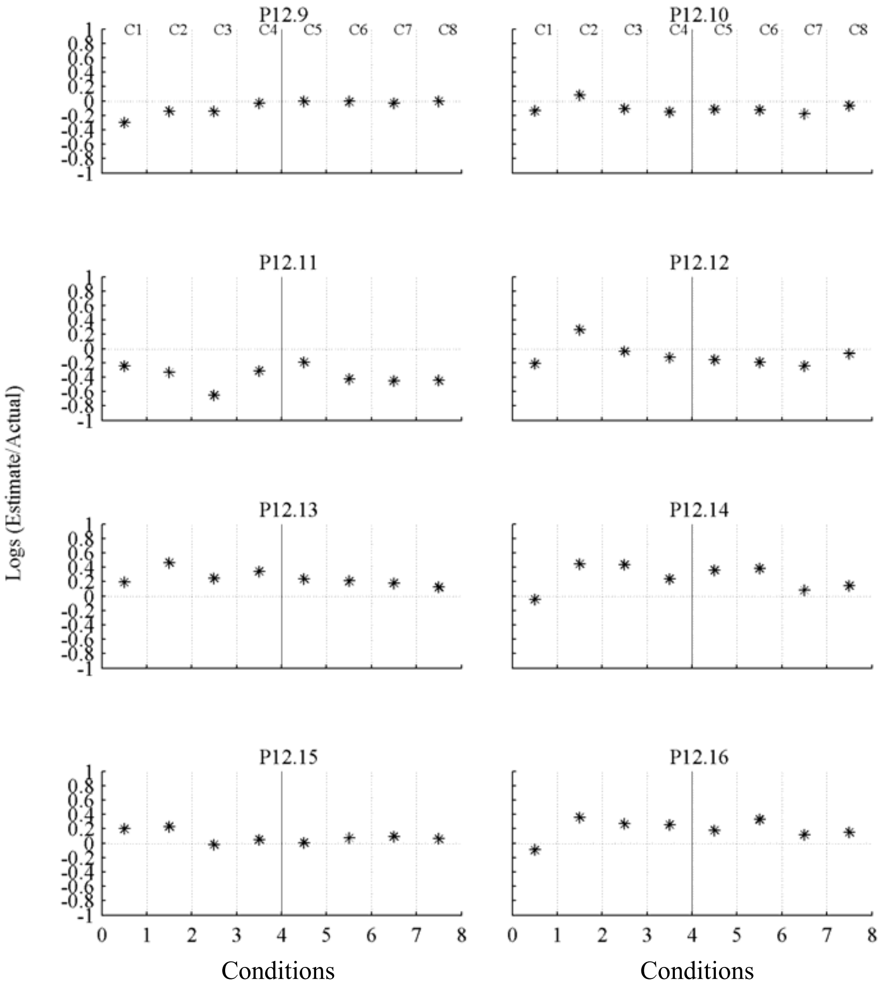

Figure 12.4. Averages of the logarithms of the estimates over the actual times, plotted against each experimental condition. P12.9-P12.16.
C1: Standard; C2: 20-s delay; C3: 60-s delay; C4: 120-s delay; C5: 120-s delay; C6: 60-s delay; C7: 20-s delay; C8: Standard.

A two-way repeated measures ANOVA was performed, with the condition manipulation and the time estimated as the within-subject variables. The ANOVA compared the means of the logarithms of the estimates over the actual times for the standard and delay conditions, and for the actual times at which estimates were made. There was a main effect of condition manipulation (F (7, 105) = 4.648, $p < .05$) on the participants' estimates of duration. The effect size was small ($\eta = .238$). There was a main effect of the times at which estimates were made (F (5, 75) = 9.567, $p < .05$). The effect size was medium ($\eta = .389$). There was an interaction between condition manipulation and the times at which estimates were made (F (35, 525) = 3.604, $p < .05$). The effect size was small ($\eta = .194$). Pairwise comparisons for the condition manipulation showed that there was a significant difference between Condition 2 (the first 20-s delay) and all other conditions and between Condition 1 and Conditions 4 and 5 ($p < .05$).
Pairwise comparisons for the times at which estimates were made showed that the log ratios from the 15-s, 30-s, 60-s and 120-s intervals were significantly different from each other ($p <.05$). Significant differences were also found between the log ratios from the 30-s, 45-s and 90-s intervals; from the 45-s, 60-s and 120-s intervals; from the 60-s and 90-s intervals, and from the 90-s and 120-s intervals ($p <.05$). There were no significant differences between the log ratios from the two standard conditions, from the two 60-s intervals and from the two 120-s intervals ($p >.05$) but there was a significant difference between the two 20-s intervals ($p <.05$).

These ANOVA results show that there were no within-session effects. There was also no significant difference between the replicated conditions, except for the 20-s delay. Given these findings, the data over the replicated conditions was combined and a two-way repeated measures ANOVA was performed, with the condition manipulation and the time at which estimates were made, as the within-subject variables. The ANOVA compared the means of the logarithms of the estimates over the actual times at which participants were required to make their estimates, for the standard and delay conditions, and for the actual times at which estimates were made. There was a main effect of condition manipulation (F (3, 45) = 5.547, $p < .05$) with a small effect size ($\eta = .270$). Pairwise comparisons showed that there was a significant difference between the standard condition and the 20-s and 120-s delay conditions ($p < .05$). There was a main effect of the times at which estimates were made (F (5, 75) = 10.305, $p < .05$). The effect size was medium ($\eta = .407$). Pairwise comparisons showed that the log ratios from the intervals were significantly different from each other (p <.05), except for those from the 30-s and 45-s intervals, and from the 90-s and 120-s intervals (p >.05). This re-analysis enables the degree to which participants overestimated or underestimated duration to be shown by the log ratio averages expressed as a percentage of the participants' under- or over-estimations of the actual time at which estimates were made. In the standard conditions, this showed that, on average, the estimates approximated the actual times, whereas in the delay conditions, duration was overestimated by 26 % for the 20-s delay, 15 % for the 60-s delay and 23 % for the 120-s delay.

Figures 12.5 and 12.6 show the total number of pieces moved in each condition by each participant. In Conditions 4 and 5 (the 120-s delay) all participants moved the same number of pieces. This also appeared to be the case for Conditions 3 and 6 (the 60-s delay) and Conditions 2 and 7 (the 20-s delay). P12.1, P12.2, P12.3, P12.4, P12.8, P12.11, P12.12, P12.13, P12.14 and P12.16 moved fewer pieces in the Condition 1 (the first standard condition) than in Condition 8 (the second standard condition). For P12.5 and P12.6, the reverse was true. P12.7, P12.9, P12.10 and P12.15 moved approximately the same number of pieces in both the standard conditions. A one-way repeated measures ANOVA was performed, with the number of pieces moved in each condition as the within-subjects variable. The ANOVA compared the number of pieces moved for the condition manipulation. There was a main effect of the number of pieces that were moved (F (7, 105) = 83.831, $p < .05$) and the effect size was large (η = .848). Pairwise comparisons showed that the number of pieces moved in all conditions where the delay differed were significantly different from each other ($p < .05$), except for the conditions with the same delay (i.e., Conditions 4 and 5, Conditions, 3 and 6, and Conditions 2 and 7) ($p > .05$).

Table 12.1 shows the time spent with the jigsaw puzzle visible to each participant in each delay condition. This was calculated my multiplying the number of pieces moved in each condition by the condition delay and subtracting this result from the length of the condition. In Conditions 4 and 5, this calculation shows that all participants did not wait to move a puzzle piece. In appears that this would be unlikely and if true, the last delay would have been shorter than 120 s as it would terminate when the 6 min condition finished. Inspection of the individual data files revealed that participants did wait for one or two

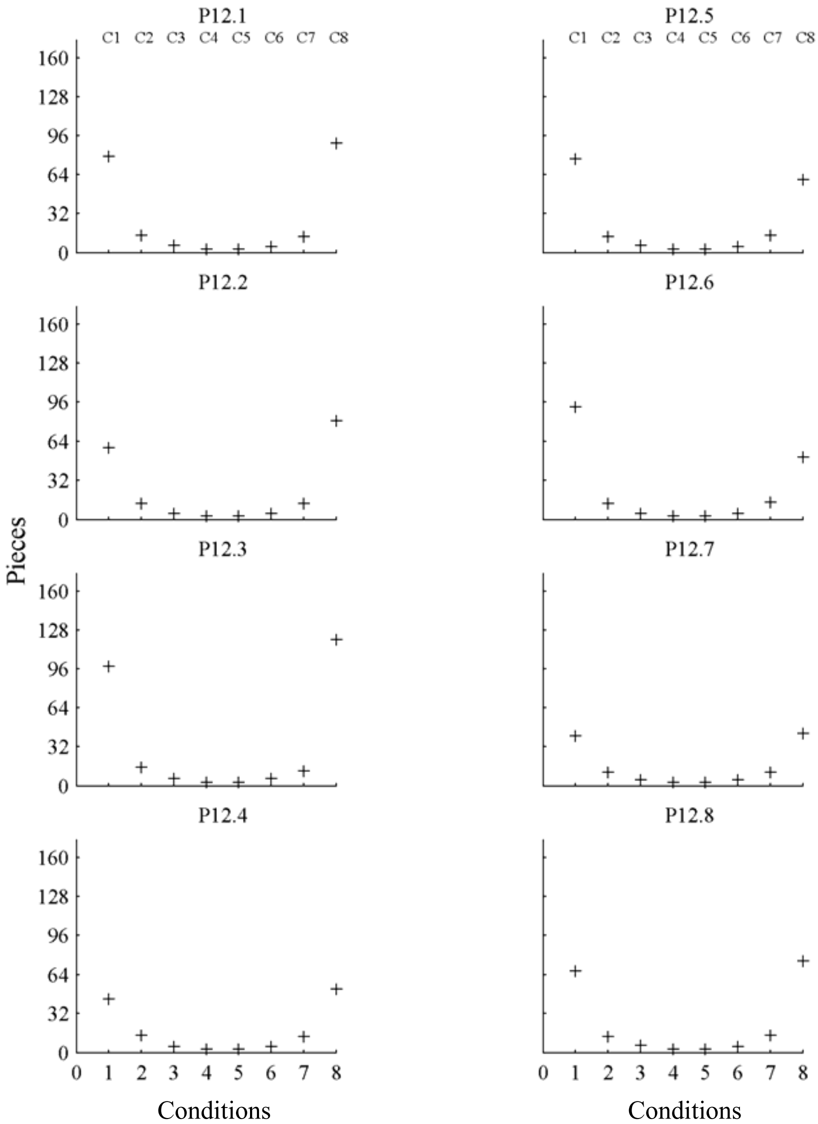

Figure 12.5. Number of pieces moved, plotted against each experimental condition. P12.1-P12.8: C1 & C8: standard; C2 & C7: 20-s delay; C3 & C6: 60-s delay; C4 & C5: 120-s delay.

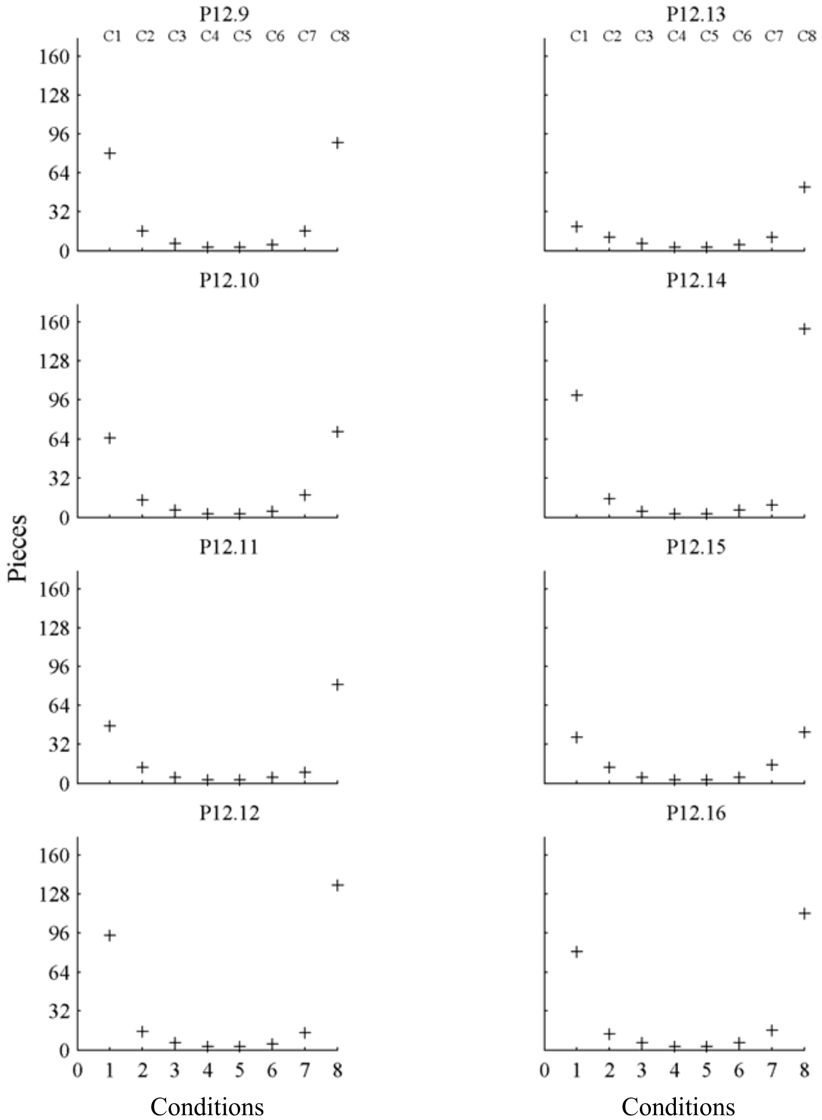

Figure 12.6. Number of pieces moved, plotted against each experimental condition. P12.9-P12.16: C1 & C8: standard; C2 & C7: 20-s delay; C3 & C6: 60-s delay; C4 & C5: 120-s delay.

Table 12.1

Time spent (s) with the puzzle visible to each participant for each condition.

	Delay Conditions					
Participants	C2 20 s	C3 60 s	C4 120 s	C5 120 s	C6 60 s	C7 20 s
P12.1	80	0	0	0	60	100
P12.2	100	60	0	0	100	100
P12.3	60	0	0	0	0	120
P12.4	80	60	0	0	60	100
P12.5	100	0	0	0	60	80
P12.6	100	60	0	0	60	80
P12.7	140	60	0	0	60	140
P12.8	100	0	0	0	60	80
P12.9	40	0	0	0	60	40
P12.10	80	0	0	0	60	0
P12.11	100	60	0	0	60	180
P12.12	60	0	0	0	60	80
P12.13	140	0	0	0	60	140
P12.14	60	60	0	0	0	160
P12.15	100	60	0	0	60	60
P12.16	100	0	0	0	0	40

seconds before moving a puzzle piece and that the condition finished before the 120 s delay timed out. In Conditions 3 and 6, participants generally waited 60 s before deciding to move a puzzle piece. In Conditions 2 and 7, the times participants waited varied between 40 s and 140 s.

Figure 12.7 shows the averages of the logarithms of the estimates over the actual times at which participants were required to make their estimates, together with the 95-percent confidence interval, plotted against the standard and three delay conditions within the session. It can be seen that during the standard conditions, duration was slightly underestimated, on average, by all participants, whereas for the three delay conditions, duration was slightly overestimated.

Figure 12.8 shows the averages of the logarithms of the estimates over the actual times, together with the 95-percent confidence interval, plotted against the times at which estimates were made. It can be seen from Figure 12.8 that the log ratios decreased as the times at which estimates were to be made increased. Duration was overestimated more at the shorter intervals (i.e., 15 s, 30 s and 45 s) than at the longer intervals.

The averages of the logarithms of the estimates over the actual times, together with the 95-percent confidence interval, plotted against the times at which estimates were made for the standard and delay conditions are shown in Figures 12.9 and 12.10 respectively. The same trend observed in Figure 12.8 can be seen in Figure 12.10. In Figure 12.9, duration is not overestimated as much at the 15 s, 30 s and 45 s intervals compared to Figures 12.8 and 12.10.

Discussion

In this experiment, participants' access to the jigsaw puzzle was limited and the reinforcement rate was controlled in six of the eight experimental conditions. This was to determine whether the statistically significant effect found in Experiment 11 was a result of reducing the reinforcement rate or of participants not having access to the jigsaw puzzle. The ANOVA results showed that effects of the manipulation were replicated in the second half of the session and that there were not statistical differences between the standard, 60-s and 120-s delay conditions. There was a statistical difference found between the two 20-s delay conditions. This was probably to be expected, as participants encountering the first delay condition (which was 20 s) would have noticed a decrease in how many pieces they

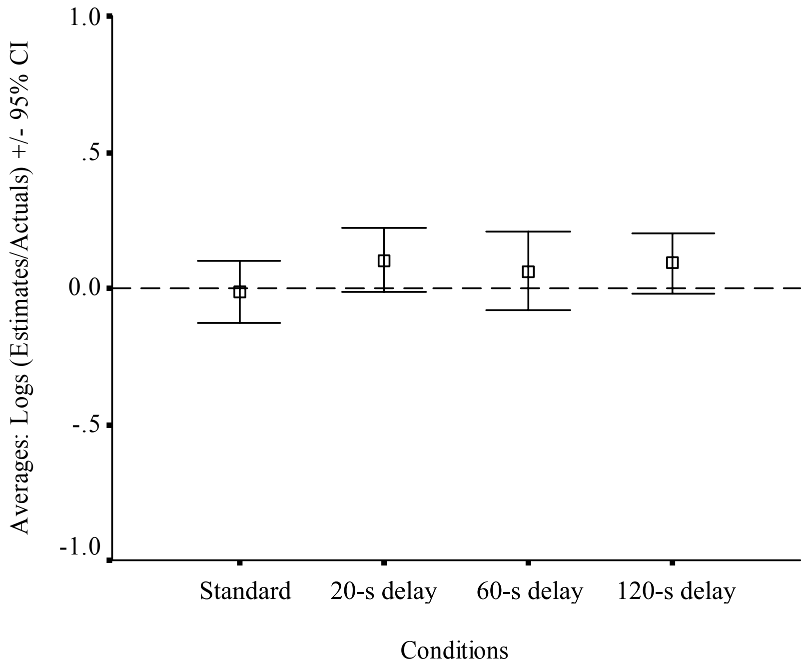

Figure 12.7. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, plotted against the standard and delay conditions within the session.

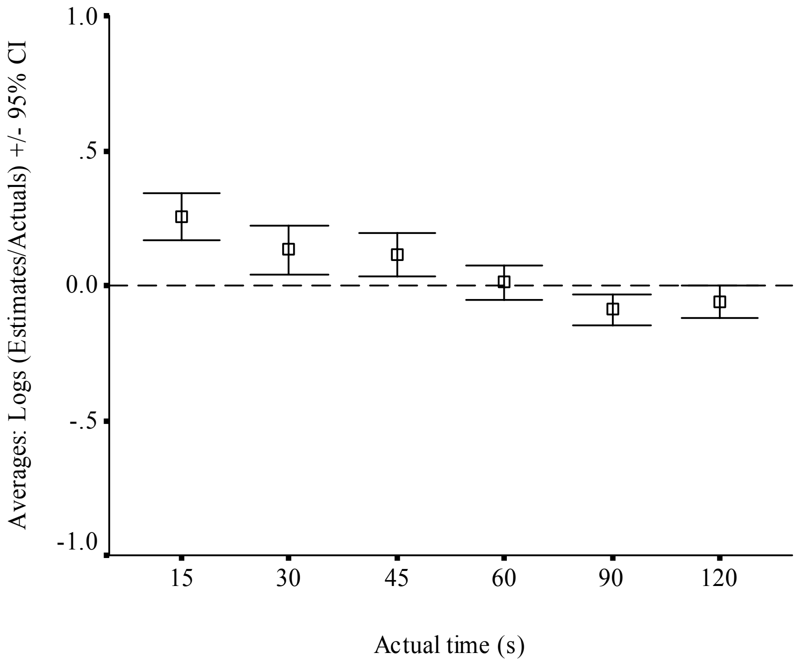

Figure 12.8. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, plotted against the times at which estimates were made.

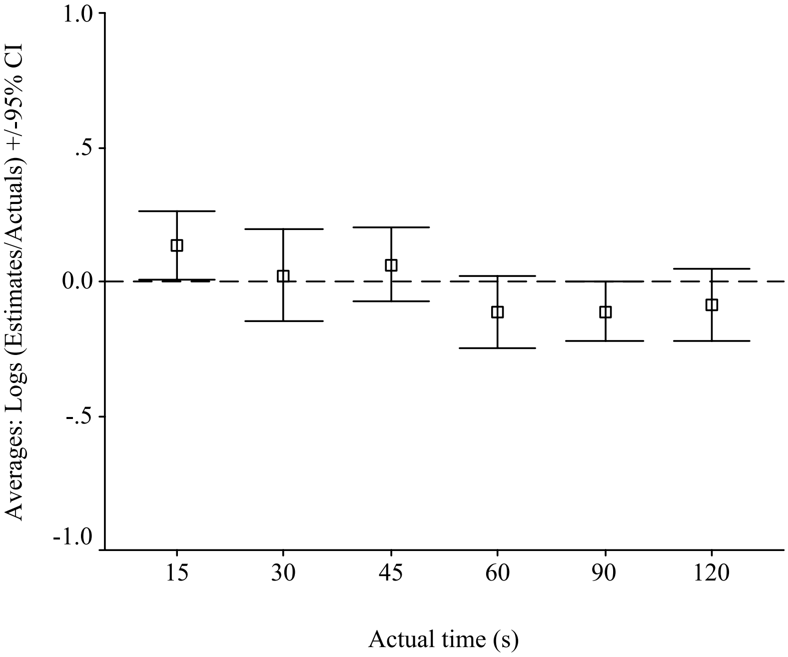

Figure 12.9. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, plotted against the times at which estimates were made, for the standard conditions.

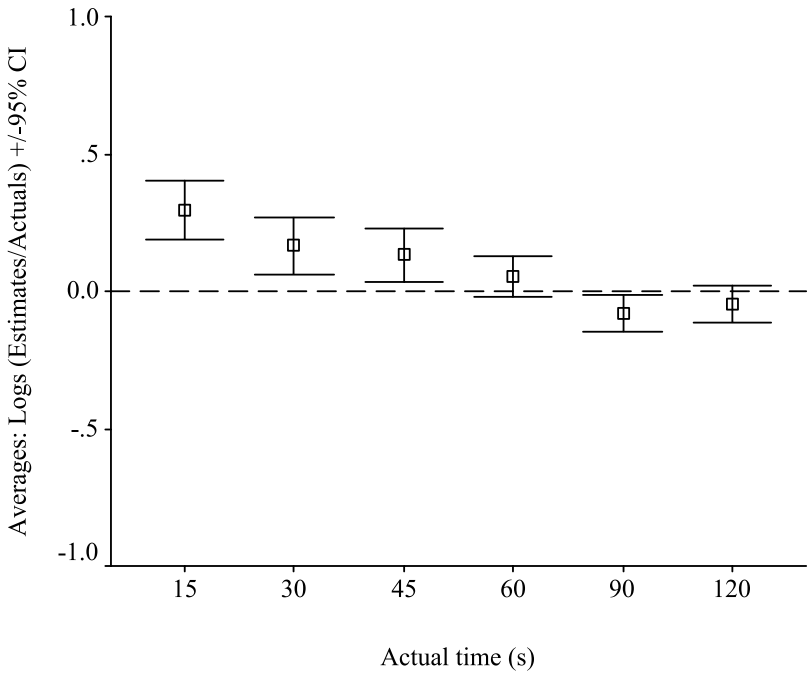

Figure 12.10. Averages of the logarithms of the estimates over the actual times, plus or minus the 95-percent confidence interval, plotted against the times at which estimates were made, for the delay conditions.

were able to move and how much access they had to the puzzle compared to the standard condition.

Table 12.1 suggests that exposure to the jigsaw puzzle was similar across the same delay conditions. During the 60-s and the 120-s delay conditions, participants generally, did not wait to move a puzzle piece once they had access to do so. Inspection of individual data files showed that participants during the 120-s delay condition, for example, were exposed to the puzzle piece for 1 to 2 seconds, before moving a puzzle piece. Thus, this response latency indicates that the times spent with the puzzle visible, as shown in Table 12.1, are approximate estimates. In the 20-s delay condition it appears that participants did wait longer before moving a puzzle piece. This suggests that the reinforcement rate (i.e., successfully moving a puzzle piece) was not controlling how participants estimated duration. If there was control by the reinforcement rate, participants would not have spent time viewing the puzzle before moving a puzzle piece. Rather, it would be expected that they would move as many puzzle pieces as possible during the condition, resulting in less exposure to the puzzle. This was not the case, as it appears participants did spend time viewing the puzzle before moving a puzzle piece.

Figures 12.5 and 12.6 showed that more pieces were moved in the standard conditions than in the delay conditions. In some cases, participants moved more pieces in the second standard condition, although not always (as was the case in the previous BeT experiments). Figures 7.4, 8.4, 9.4 and 10.4 showed that more pieces were moved in the second jigsaw/standard condition compared to the first jigsaw/standard condition. These results suggest that the carry-over effect in Experiments 7, 8, 9 and 10 did not eventuate in this experiment. Thus, the shift in the reinforcement rate was not as effective here as it was in the previous BeT experiments. During the delay conditions, fewer pieces were moved as the delays that were controlling access to the puzzle, increased. Thus, there was control by the reinforcement rate.

The results from this experiment, when compared to those from Experiment 11 and to those from Experiments 7 to 10, suggest that not having access to the jigsaw puzzle rather than any control of the reinforcement rate is what affected participants' estimates of duration. Control by the reinforcement rate would result in differences in estimations of duration between each of the delay conditions. This was not the case. In Experiments 7 to 10, participants always had access to the jigsaw puzzle, even when the reinforcement rate was being varied. However, when access to the jigsaw puzzle was removed in Experiment 11 (and consequently the reinforcement rate was zero) there was a statistically significant effect on how participants estimated duration (i.e., duration was overestimated in the blank conditions).

It is possible that the presence of the jigsaw puzzle may have enabled participants to engage in ‘private’ behaviour (e.g., planning a future move or comparing the appearance of two pieces to see if they match) whilst they have access to the jigsaw puzzle (as they did in Experiments 7 to 10). Thus, participants were still actively working towards the completion of the jigsaw puzzle, even though they were unable to move pieces. When there is no access to the jigsaw puzzle (i.e., Experiment 11) participants are not able to engage in ‘private’ behaviour and consequently, overestimate duration. It appears that so long as the jigsaw is available to the participants time will not be perceived to drag. The presence of the jigsaw puzzle therefore, may constitute some form of information that can be used by participants to assist them in completing their jigsaw puzzle.

GENERAL DISCUSSION

This thesis investigated the perception of how time passes in an attempt to show how a task a person is engaged in affects their estimation of duration. Contrary to previously published findings, in the first four experiments it was not reliably demonstrated that task complexity had an effect on people's perception of time passing. In the first four experiments, the number of the pieces in the puzzle was changed, as was the colour of the puzzle and two separate measures of duration were compared. Despite these attempts to vary participant's estimates of duration, as predicted by previous research on task complexity (e.g., Allen, 1980; Axel, 1924; Loehlin, 1959; Smith, 1969) no significant results were obtained (i.e., there was no support that varying the complexity of a task affected estimates of duration). In order to establish why no significant results were obtained, replications of two previously reported task complexity studies (Allen, 1980; Hogan, 1975) were conducted. The replications did not return significant results and therefore, do not support the general theoretical view, prevalent in task complexity literature, that estimates of duration are underestimated for complex tasks and overestimated for simple tasks.

These findings lead to two possible conclusions. Firstly, that there is no reliable relationship between task complexity and perceived duration. The second possible conclusion is that there was no manipulation of task complexity at all, despite efforts of trying to do so. The question arises then, if any of these possible conclusions is correct? To establish if the first conclusion is correct relies upon being assured that the independent variable of task complexity was varied. However, the task complexity literature does not provide any clear definitions of what task complexity is. Rather, it appears from the task complexity literature that researchers have arbitrarily defined task complexity based on the type of task being used. For example, in Hogan's (1975) study, it was assumed that line drawings with more interior angles were more complex than those with fewer interior angles and consequently, that time should be perceived as going faster when drawings with more interior angles are compared to drawings with fewer interior angles. However, there is no way of knowing if drawings with more interior angles will produce estimates of time passing quickly, before the research is conducted. Or, in other words, whether drawings with more interior angles are complex is not established independently before the research commences, thus it is unclear that the putative independent variable functions as envisaged by the researchers.

Not being able to independently establish whether a task is simple or complex (i.e., defining what task complexity is) means that there can be no answer given to the first possible conclusion (i.e., that there was no reliable relationship between task complexity and perceived duration). If there is no reliable definition of task complexity, then it cannot be demonstrated that such a reliable relationship exists. The results from the two task complexity replications (Experiments 5 and 6) support this argument as these results were not replicated. The second conclusion (i.e., that there was no manipulation of task complexity) cannot be tested either, as there is no independent definition of task complexity. Another approach is needed to show how the tasks that people are doing affects how they estimate time to be passing.

BeT (Killeen & Fetterman, 1988, 1993) offered another theoretical approach to assessing how people's estimates of time are affected by the task they may happen to be doing. The basic premise of BeT is that an organism's perception of time is affected by the rate of reinforcement it receives during that time. In the context of doing jigsaw puzzles, this means controlling the reinforcement rate (i.e., the rate of successful puzzle pieces relocated within a minute). The advantage of BeT is that it relies upon reinforcement rate, a concept rigorously studied in animal and human research, as the independent variable, which can be reliably manipulated and independently defined. In comparison, task complexity cannot be independently defined. Therefore, BeT, given its reliability, may be able to explain why the first series of task complexity experiments didn't affect, as expected, how participants estimated time to be passing. BeT would predict that simply changing the number of pieces in the puzzle does not necessarily alter the reinforcement rate, that is, the number of pieces a person can move per minute is not controlled by the number of pieces in the jigsaw puzzle. It is assumed that moving puzzle pieces per unit time is what constitutes reinforcement. In the task complexity experiments, no restriction was placed on the rate at which puzzle pieces could be moved. Thus, how participants estimated duration in the task complexity experiments would not be as predicted by BeT. This is because there was no change in the reinforcement rate, irrespective of either the 'complex' or the 'simple' conditions.

Two task complexity studies involving playing cards (Allen, 1980) and line drawings (Hogan, 1975) were partially replicated but returned non-significant results. However, these non-significant results could also be explained by BeT. In Allen's (1980) study, participants sorted cards for a set duration period and then made an estimate of the time they thought they had been card sorting. In Hogan's (1975) study, participants were first shown a standard line drawing, followed by a comparison line drawing (both were presented for the same duration). Participants were then asked to make an estimate of the length of time they thought the comparison drawing had been presented compared to the standard drawing. In these two experiments, it appears that there was no reinforcement.

The way in which BeT could explain the results of the two replication studies is around the idea of what constitutes a reinforcer. In the jigsaw puzzle, moving a puzzle piece constituted a reinforcer, in that, by successfully moving a puzzle piece a participant would get feedback showing whether the piece had been correctly or incorrectly moved. Additionally, moving puzzle pieces would eventually lead to the completion of the puzzle. Arguably, Allen's (1980) and Hogan's (1975) studies did not involve the use of a reinforcer. Sorting cards and viewing drawings do not, in and of themselves, constitute reinforcement (in the same way that moving a puzzle piece does). Unlike jigsaw, placing a card on a particular pile or viewing slides of line drawings produces no feedback about the efficacy of the action. Thus, the non-significant results from the two replicated studies, from a BeT perspective, were not surprising as there was no manipulation of the reinforcement rate, because there was no reinforcer that could be manipulated in the first place. However, this does not explain the significant results from Allen's (1980) and Hogan's (1975) studies. This issue will be addressed later in this discussion.

In the second series of experiments (seven through ten), referred to as the BeT series, the reinforcement rate was successfully manipulated as shown by the number of pieces moved, but participants did not estimate time passing as predicted by BeT. Despite successfully manipulating the apparent reinforcement rate, it is not clear however, that this was the only way a person could access reinforcement whilst working on the task. A possible reason why time was not estimated as expected, might be because participants were still able to 'get things done' (Lee, 1994) or obtain 'outcomes' (Dube & Schmitt, 1996). Lee (1994) suggested that an organism behaves in order to bring about changes in the world around it. "A thing is done only once a specified change has been brought about" (Lee, 1994, p 15). Dube and Schmitt (1996), who investigated how social situations that unfold over time, in relation to an individual's expectations about obtaining outcomes, suggested that as long as organisms can behave towards achieving an outcome, time will be not be perceived as going slow. It may be possible that participants did not estimate duration as expected in the BeT experiments because they were still able to behave, and thus, continue to do the jigsaw puzzle in some way and thus, keep the rate of reinforcement constant, in spite of the manipulation. The experimental conditions of the jigsaw puzzles for the BeT series, involved slowing down the distance a puzzle piece could be moved, relative to the distance the mouse could be moved; fixing the speed at which a puzzle piece could be moved and increasing stimulus intensity by using visual and operational cues. These changes however, in no way limited a participant's ability to continue behaving, albeit privately (e.g., thinking) (Skinner, 1969) or publicly (e.g., moving the computer mouse). There may have been other behaviours occurring when the reinforcement rate was being manipulated, analogous to a chess player planning their next move, whilst waiting for their opponent to make their move. A participant could still observe the jigsaw and as such, might have been privately planning out how they could make their next move. Thus, when the opportunity again became available for them to move puzzle pieces, participants were able to do that, perhaps moving more puzzle pieces due to the time that might have been spent working out how they could make their next move. The results from Experiment 8 (see Figure 8.4) show that this could have happened, as participants moved more pieces after the manipulation conditions, than before the manipulation conditions. If this is the case, envisaging moving puzzle pieces to locations may itself constitute a reinforcer. Private behaviour such as this seems to suggest that participants are still getting things done or are obtaining outcomes and therefore, may account for why participants did not estimate duration as predicted by BeT.

Another possible reason for explaining why participants did not estimate duration as expected during the BeT experimental series is the idea of the informative properties of stimuli (Dinsmoor, 1983; Wyckoff, 1952). Stimuli can contain information that maintains observing behaviour or explicit attentional responses (Case, 1995). In computer web-based studies information is contained in stimuli presented to a computer user which in turn affects their responses (e.g., Gorn, Chattopadhyay, Sengupta & Tripathi, 2004; Gueguen & Jacob, 2002; Nah, 2004). In other words, information can act as reinforcement.

The idea of stimuli containing information that can act as reinforcement might have affected the way in which participants estimated duration during the BeT experimental series. The jigsaw puzzle was always available for participants to view and in this sense participants could use this information for making a response, whether public or private. When the reinforcement rate (i.e., the number of pieces able to be moved) was being manipulated, for example, a participant's public behaviour (e.g., moving the mouse) did not result in being able to move a jigsaw piece. However, a participant could still engage in private behaviour and think about how they could make their next move. Thus, with the continual presence of the jigsaw puzzle on the screen, continual information was being made available to the participant, which allowed them to behave privately. Hence, participants did not estimate duration as predicted by BeT as they were still receiving reinforcement in the form of information.

In Experiment 11, a significant result was obtained when the opportunity to publicly and privately do the jigsaw puzzle was removed. During the blank condition, participants could not get 'things done' or use information as a form of reinforcement. Thus, it appears that when participants had to sit and wait, with no access to information and therefore, unable to behave privately, time dragged, whereas when participants were able to move puzzle pieces, time flew. Comparing the results of Experiment 11 to the results of the BeT experiments, suggests that time will be overestimated when participants are unable to do the jigsaw (i.e., publicly or privately).

The results from Experiment 12 further support the idea that when participants do not have an opportunity to behave (i.e., do jigsaw), either publicly or privately, time will be perceived to drag. In the delay conditions, participants had the opportunity to move a puzzle piece and once a puzzle piece was moved, the screen went blank for a set duration. The number of opportunities to work at a jigsaw puzzle was increased or decreased contingent upon whether a shorter or longer delay was operating and during these conditions time was perceived to go slower, on average, by 21 percent than in the jigsaw conditions. Similarly, in Experiment 11, time was perceived to go slower in the blank conditions than in the jigsaw conditions. These results suggest that perhaps varying the reinforcement rates may result in estimates of duration that are in proportion to the degree of reinforcement rate manipulation. However, this was not able to be demonstrated in Experiment 12 as there were no effects of arranged reinforcement rates upon how participants estimated duration. This might be due to there being no perceptible difference between the each of the delay conditions. For example, participants could only move a single puzzle piece in the delay conditions before the screen went blank. Or in other words, there was very limited information (i.e., reinforcement) available, which didn't differ between any of the delay conditions. Thus, irrespective of how long participants had to wait while the screen was blank before being able to move another puzzle piece, there may have been no perceptible difference between either of the three delay conditions and therefore, participants didn't perceive time differently.

It is also possible, that the arranged reinforcement rates do not contribute to the control of how duration is estimated. Participants in Experiment 12 did not move the maximum number of puzzle pieces available to them in the manipulation conditions. Participants spent time viewing the puzzle before moving a piece. Thus, it appears that information (i.e., participants viewing the puzzle, perhaps working out a move) was acting as reinforcement rather than moving puzzle pieces.

As mentioned earlier in this discussion, the significant results reported in the two previously published and partially replicated task complexity studies (i.e., Allen (1980) and Hogan (1975)) were going to be discussed in more depth. Rosenthal (1979) suggested that five percent of studies that are published are Type 1 errors, whereas the other ninety-five percent are Type 2 errors filed away and forgotten. He called this the 'file-drawer problem'. This phenomenon however, interacts with the tendency to publish positive findings, hence it must be borne in mind that there are reliable studies published. Rosenthal (1979) suggests that behavioral scientists are becoming increasingly interested in summarising entire research domains more systematically than has occurred previously, which will lead to effect sizes and significance levels being reported more frequently. These measures Rosenthal (1979) claims will enable a calculation to be made by the reviewer about the overall probability that the research question is 'real' (i.e., not a Type 1 error). The first four task complexity experiments did not produce significant results in accordance with earlier task complexity literature theory. These results suggest that the statistically significant task complexity studies that have been published might be Type 1 errors. The results from the replications of Allen's (1980) and Hogan's (1975) studies provide further support for this claim, as they failed to reproduce the original findings.

Cohen (1994) emphasised that the generalisability of results in psychology must fundamentally rely upon replication. The failure to replicate, when seen in the light of Rosenthal's (1979) file-drawer phenomenon, suggests that the earlier task complexity studies which reported significant results might in fact have not been correct. If the results of first four experiments and the two task complexity replication experiments had returned significant results, then the question of whether the previous task complexity studies were correct or not would not have arisen. However, the question does arise and with it, the need for further inquiry into the reliability of the results of the earlier task complexity studies.

Though we can never know that a particular paper constitutes a Type 1 error, there may be other evidence that leads us to be concerned. If there were a number of studies published, using the same methodology, producing significant results, then it could be claimed that the results would be reliable, as this is replication and consequently, the file-drawer phenomenon would not be an issue. However, this is not the case in the task complexity literature as there are only single studies published, by different authors, using different methodologies, claiming to have produced significant effects of task complexity upon the human estimation of duration. Thus, it can be argued that the significant effects due to the putative manipulation of complexity, though appearing to be real, may not be reliable, especially given the results of the first six experiments.

The results from this thesis suggest that people perceive time to pass slowly or quickly contingent upon whether they are receiving reinforcement. When reinforcement is reliably available, time is perceived to 'fly', as participants can continually behave publicly and achieve outcomes. Additionally, participants can also continually behave privately, achieving outcomes, in terms of reinforcement being used as information. When reinforcement is unavailable, participants cannot behave publicly or privately, hence time is perceived to 'drag'. The lack of reinforcement equates with definitions of extinction, where responses become less common and eventually cease due to lack of reinforcement (Skinner, 1957). With no reinforcement available participants are effectively, in extinction. Thus, in terms of how humans perceive time to pass, the results from this thesis showed that when reinforcement is totally withdrawn (i.e., Experiment 11) time is perceived to drag more in extinction than when there is reinforcement available.

This thesis investigated how the type of tasks that people may happen to be engaged in affects their estimates of duration. Despite the claim by task complexity researchers that time flies during filled time intervals (e.g., Fraisse, 1963), it is possible that time would only fly if the stimuli presented in a filled time interval constituted reinforcement. The results from the six task complexity studies in the first half of this thesis showed that despite there being stimuli presented (i.e., filled time intervals) time was not perceived as predicted by previous task complexity researchers. Irrespective of whether an interval is 'filled' with particular stimuli, unless that stimuli constitutes reinforcement, the filled time interval will not be perceived as going fast, as predicted by BeT. Empty time intervals appear to be analogous to extinction periods and in accordance with BeT, the prediction would be that time would be overestimated during empty time intervals.

Humans perceive time to ‘drag’ when put into extinction. During extinction, public and private behaviour is not possible. Private behaviour presupposes that information can act as reinforcement.

REFERENCES

Allan, L.G. (1979). The perception of time. *Perception & Psychophysics,* **26** (5), 340-354.

Allen, D.A. (1980). Filling time versus affective response to the activity that fills the time: Independent effects on time judgement? *Perceptual and Motor Skills,* **51** (3), Pt 1, 723-727.

Axle, R. (1924). *Estimation of time.* Unpublished Doctorate thesis, University of Columbia, New York, U.S.A.

Beam, J.J., Killeen, P.R., Bizo, L.A. & Fetterman, J.G. (1998). How reinforcement context affects temporal production and categorization. *Animal Learning and Behavior,* **26** (4), 388-396.

Bizo, L.A., & White, K.G. (1994a). The Behavioral theory of timing: Reinforcer rate determines pacemaker rate. *Journal of the Experimental Analysis of Behavior,* **60** 19-33.

Bizo, L.A., & White, K.G. (1994b). Pacemaker rate in the behavioral theory of timing. *Journal of Experimental Psychology: Animal Behavior Processes,* **20** (3), 308-321.

Bizo, L.A., & White, K.G. (1995a). Biasing the pacemaker in the behavioral theory of timing. *Journal of the Experimental Analysis of Behavior,* **62** (2), 225-235.

Bizo, L.A., & White, K.G. (1995b). Reinforcement context and pacemaker rate in the behavioral theory of timing. *Animal Learning & Behavior,* **23** (4), 376-382.

Bizo, L.A., & White, K.G. (1997). Timing with controlled reinforcer density: Implications for models of timing. *Journal of Experimental Psychology: Animal Behavior Processes,* **23** 44-55.

Cahoon, D., & Edmond, E.M. (1980). The watched pot still won't boil: Expectancy as a variable in estimating the passage of time. *Bulletin of the Psychonomic Society,* **16** 115-116.

Case, D.A. (1995). On trekking to operant frontiers. *Behavior Research Methods, Instruments & Computers*, **27** (2), 211-216.

Casini, L., & Macar, F. (1997). Effects of attention manipulation on judgements of duration and of intensity in the visual modality. *Memory & Cognition,* **25** (6), 812-818.

Chiesa, M. (1994). *Radical behaviorism: The philosophy and the science.* Boston, MA, US: Authors Cooperative, Inc.

Cohen, J. (1994). The earth is round ($p < .05$). *American Psychologist,* **49** (12), 997 – 1003.

Cottle, T.J., & Klineberg, S.L. (1974). *The Present of Things Future.* New York: The Free Press.

Craik, F.I.M., & Hay, J.F. (1999). Aging and judgments of duration: Effects of task complexity and method of estimation. *Perception and Psychophysics,* **61** (3), 549-560.

Creelman, C.D. (1962). Human discrimination of auditory stimulil. *Journal of the Acoustical Society,* **34** 582-593.

DeWolfe, R.K.S., & Duncan, C.P. (1959). Time estimation as a function of level of behavior of successive tasks. *Journal of Experimental Psychology,* **58** (2), 153-158.

Dinsmoor, J.A. (1983). Observing and conditioned reinforcement. *Behavior & Brain Sciences,* **6** 693-728.

Dube, L., & Schmitt, B. (1996). The temporal dimension of social episodes: Position effect in time judgements of unfilled intervals. *Journal of Applied Social Psychology,* **26** (20), 1816-1826.

Eysenck, H.J. (1957). *The dynamics of anxiety and hysteria.* London. Routledge & Keegan Paul.

Fetterman, J.G., & Killeen, P.R. (1990). A componential analysis of pacemaker-counting timing systems. *Journal of Experimental Psychology: Human Perception and Performance,* **16** (4), 766-780.

Fetterman, J.G. & Killeen, P.R. (1991). Adjusting the Pacemaker. *Learning and Motivation,* **22** 226-252.

Fetterman, J.G. & Killeen, P.R. (1992). Time discrimination in Columba livia and Homo sapiens. *Journal of Experimental Psychology: Animal Behavior Processes,* **18** (1), 80-94.

Fetterman, J.G., Dreyfus, L.R., & Stubbs, D.A. (1989). Discrimination of Duration Ratios. *Journal of Experimental Psychology: Animal Behavior Processes,* **15** (3), 253-263.

Fetterman, J.G., Dreyfus, L.R., & Stubbs, D.A. (1993). Discrimination of Duration Ratios by Pigeons (*Columba livia*) and Humans (*Homo sapiens*). *Journal of Comparative Psychology,* **107** (1), 3-11.

Fetterman, J.G., Dreyfus, L.R., & Stubbs, A.L. (1996). Judging relative duration: The role of rule and instructional variables. *Journal of Experimental Psychology: Animal behavior processes,* **22** (3), 350-361.

Flaherty, M.G. (1999). *A watched pot. How we experience time.* New York: New York University Press.

Fraisse, P. (1963). *The psychology of time.* New York: Harper & Row.

Gorn, G.J., Chattopadhyay, A., Sengupta, J., & Tripathi, S. (2004). Waiting for the web: How screen color affects time perception. *Journal of Marketing Research*, **41** 215-225.

Gray, C.T., Gray, C.R., & Loehlin, J.C. (1975). Time perception: Effects of introversion / extroversion and task interest. *Perceptual & Motor Skills,* **41** (3), 703-708.

Gueguen, N., & Jacob, C. (2002). Social presence reinforcement and computer mediated communication: The effect of the solicitor's photography on compliance to a survey request made by e-mail. *Cyber Psychology & Behavior,* **5** (2), 139-142.

Gulliksen, H. (1927). The influence of occupation upon the perception of time. *Journal of Experimental Psychology,* **10** 52-59.

Harton, J. (1938). The influence of the difficulty of activity on the estimation of time. *Journal of Experimental Psychology,* **23** 270-287, 428-433.

Hawkins, M.F., & Tedford, W.H. (1976). Effects of interest and relatedness on estimated duration of verbal material. *Bulletin of the Psychonomic Society,* **8** (4), 301-302.

Hicks, R.E., Miller, G.W., & Kinsbourne, M. (1976). Prospective and retrospective judgements of time as a function of amount of information processed. *American Journal of Psychology,* **89** 719-730.

Hicks, R.E., Miller, G.W., Gaes, G., & Bierman, K. (1977). Concurrent processing demands and the experience of time-in-passing. *American Journal of Psychology,* **90** 431-446.

Hogan, H.W. (1975). Time perception and stimulus preference as a function of stimulus complexity. *Journal of Personality and Social Psychology,* **31** (1), 32-35.

Jones, M.R., & Boltz, M. (1989). Dynamic attending and response to time. *Psychological Review,* **96** 459-491.

Juhnke, R., & Scott, J.N. (1988). Psychology of computer use: V. Computer use and the experience of time. *Perceptual and Motor Skills,* **67** 863-870.

Killeen, P.R., & Fetterman, J.G. (1988). A behavioral theory of timing. *Psychological Review,* **95** (2), 274-295.

Killeen, P.R., & Fetterman, J.G. (1993). The behavioral theory of timing: Transition analyses. *Journal of the Experimental Analysis of Behavior,* **59** 411-422.

Killeen, P.R., Hall, S. & Bizo, L.A. (1999). A clock not wound runs down. *Behavioural Processes,* **45** 129-139.

Lee, V.L. (1994). Organisms, things done and the fragmentation of psychology. *Behavior & Philosophy,* **22** (2), 7-48.

Loehlin, J.C. (1959). The influence of different activities on the apparent length of time. *Psychological Monographs: General and Applied,* **73** (4), (Whole No. 474), 1-27.

Mattes, S., & Ulrich, R. (1998). Directed attention prolongs the perceived duration of a brief stimulus. *Perception & Psychophysics,* **60** (8), 1305-1317.

Morgan, L., Killeen, P.R & Fetterman, J.G. (1993). Changing rates of reinforcement perturbs the flow of time. *Behavioural Processes,* **30** 259-272.

Nah, F.F. (2004). A study on tolerable waiting time: How long are Web users willing to wait? *Behaviour & Information Technology*, **23** (3), 153-163.

Orme, J.E. (1969). *Time, experience and behaviour.* London: Iliffe Books Ltd.

Ornstein, R.E. (1969). *On the experience of time.* Harmondsworth: Penguin.

Ornstein, R.E. (1975). *On the experience of time.* New York: Pelican.

Quingley, J.J., Combs, A.L., & O'Leary, N. (1984). Sensed duration of time: Influence of time as a barrier. *Perceptual and Motor Skills,* **58** 72-74.

Rosenthal, R. (1979). The "File drawer problem" and the tolerance for null results. *Psychological Bulletin,* **86** (3), 638-641.

Rosenzweig, S., & Koht, A.G. (1933). The experience of duration as affected by need-tension. *Journal of Experimental Psychology,* **16** 745-774.

Sawyer, T.F., Meyers, P.J., & Huser, S. J. (1994). Contrasting task demands alter the perceived duration of brief time intervals. *Perception and Psychophysics,* **56** (6), 649-657.

Skinner, B.F. (1957). *Verbal behavior.* New York. Appleton-Century-Crofts.

Skinner, B.F. (1969). Behaviorism at fifty. In *Contingencies of reinforcement.* New York. Appleton-Century-Crofts.

Smith, N.C. (1969). The effect on time estimation of increasing the complexity of a cognitive task. *Journal of General Psychology,* **81** 231-235.

Stelmach, L.B., & Herdman, C.M. (1991). Directed attention and perception of temporal order. *Journal of Experimental Psychology: Human Perception & Performance,* **17** 539-550.

Stelmach, L.B., Herdman, C.M., & McNeil, K.R. (1994). Attention modulation of visual processes in motion perception. *Journal of Experimental Psychology: Human Perception & Performance,* **20** 108-121.

Sumpter, C., & McEwan, J. (2003). Perceptual outcomes as reinforcers. *Experimental Analysis of Human Behavior Bulletin,* **21** 35-38.

Thomas, E.A.C., & Weaver, W.B. (1975). Cognitive processing and time perception. *Perception & Psychophysics,* **17** 363-367.

Treisman, M. (1963). Temporal discrimination and the indifference interval: Implications for a model of the "internal clock." *Psychological Monographs*, **77** 1-31.

Treisman, M., Faulkner, A., Naish, P.L.N., & Brogan, D. (1990). The internal clock: Evidence for a temporal oscillator underlying time perception with some estimates of its characteristic frequency. *Perception*, **19** 705-748.

Troutwine. R., & O'Neal, C. (1981). Volition, performance of a boring task and time estimation. *Perceptual & Motor Skills,* **52** (3), 865-866.

Watt, J. (1991). Effect of boredom proneness on time perception. *Psychological Reports,* **69** (1), 323-327.

Wearden, J.H., Philpott, K., & Win, T. (1999). Speeding up and (relatively) slowing down an internal clock in humans. *Behavioural Processes,* **46** 63-73.

Wilsoncroft, W.E., Stone, J.D., & Bagrash, F.M. (1978). Temporal estimates as a function of difficulty of mental arithmetic. *Perceptual and Motor Skills,* **46** 1311-1317.

Wyckoff, L. B., Jr. (1952). The role of observing responses in discrimination learning: Part 1. *Psychological Review,* **59** 431-442.

Zakay, D., Nitzan, D., & Glicksohn, J. (1983). The influence of task difficulty and external tempo on subjective time estimation. *Perception and Psychophysics,* **34** (5), 451-456.

APPENDIX

The Appendix is a CD containing the raw data from all the experiments and a representative sample of experimental software.