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RUNNING HEAD: TESTING TWO COGNITIVE THEORIES OF INSIGHT

Testing Two Cognitive Theories of Insight

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Abstract

Insight in problem solving occurs when the problem solver fails to see how to solve a problem and then – “aha!” – there is a sudden realization how to solve it. Two contemporary theories have been proposed to explain insight. The representational change theory (e. g., Knoblich et al., 2001) proposes that insight occurs through relaxing self-imposed constraints on a problem, and by decomposing chunked items in the problem. The progress monitoring theory (e. g., MacGregor et al., 2001) proposes that insight is only sought once it becomes apparent that the distance to the goal is unachievable in the moves remaining. These two theories are tested in an unlimited move problem, to which neither theory has previously been applied. The results lend support to both, but experimental manipulations to the problem suggest that the representational change theory is the better indicator of performance. The findings suggest that testable opposing predictions can be made to examine theories of insight, and that the use of eye movement data is a fruitful method of both examining insight and testing theories of insight.

Introduction

Insight in problem solving occurs when the problem solver fails to see how to solve a problem and then – "aha!" – there is a sudden realization how to solve it. The realization of how to solve the problem is usually preceded by an impasse (Kaplan & Simon, 1990), where the problem solver becomes stuck and cannot see how to solve the problem. The impasse often consists of either a period of time where no problem solving activity takes place, or where the same problem solving activity is repeated time and again. Insight is an interesting phenomenon because the subsequent solving of the problem means that the problem solver was competent enough to accomplish the task to begin with, begging the questions of why they encountered an impasse and how their insight was gained (Ohlsson, 1992).

Insight has been demonstrated on numerous occasions within problem solving. Maier (1931) used a task where two pieces of string were attached to a ceiling but were far enough apart so as they could not both be held at the same time. The task was to tie the pieces of string together. Various objects were located in the room, the solution being to tie an object to one of the pieces of string so that a pendulum motion can be achieved. Problem solvers in this task had great difficulty in solving it, the majority requiring a hint (the experimenter "accidentally" brushing against the string to cause a swinging motion) before they had the insight for how to solve the problem. Duncker (1945) gave the task of mounting a candle onto a vertical screen, with various objects being provided such as a box of nails and a book of matches. The insight here is to realize that the box can be used outside of its main function (i. e., as the base on which to place the candle, rather than for holding nails).

Perhaps the most common insight problem solving task is the nine-dot problem (e. g., Scheerer, 1963). Nine dots are arranged in a three-by-three two-dimensional square with the task being to use a pen to bisect all of the dots using four lines only, without taking the pen off the paper and without retracing any lines or parts of lines. In experiments which use the standard version of the problem as outlined, no participants are able to solve the problem, even when they are given ten minutes to solve it (Burnham & Davis, 1969) or given one hundred attempts in which to solve it (Weisberg & Alba, 1981). The solution can be achieved by realizing that lines have to be drawn that go beyond the imagined outline of the square, although explicitly informing participants of this does not necessarily lead to an improved performance (Weisberg & Alba, 1981).

The Progress Monitoring Theory

MacGregor, Ormerod, and Chronicle (2001) propose a theory of insight problem solving based around the hill-climbing idea that problem solving proceeds with the problem solver seeking to minimize the gap between the current state of the problem and the goal state. Impasse will only occur when the problem solver finds that the hill-climbing method does not give rise to the solution, and it is only at this point that alternative approaches will be considered.

Insight in MacGregor et al. 's theory is governed by examining the difference between the current state of the problem and the goal state (or even a sub-goal state), and comparing this with the number of moves that are remaining with which to solve the problem (or to reach the sub-goal state). When there is a large distance between the current state and the goal state with only a small number of moves remaining, then it is likely that criterion failure will be reached. Criterion failure is a failure to reach a minimum distance from the current state to the goal state. When criterion failure occurs, there is a high potential that the problem solver will seek alternative solutions. This is one area where individual differences may occur in insight problem solving (where “insight potential” varies across individuals).

For the nine dot problem, MacGregor et al. state that problem solvers will seek to maximize the number of dots they cross out with each successive line that they draw. The minimum amount of dots that must be crossed out is just over two on average (nine dots to cross out using four lines). As it is quite easy to cross out three dots with the first line, and two with the next two lines, then for the first three moves there is never a large difference between the current state of the problem (in terms of how many uncrossed dots exist) and the number of moves remaining (in terms of how many lines have yet to be drawn). Criterion failure is only encountered on the fourth and final move. The poor performance on the nine dot problem is therefore explained by criterion failure being reached too late, rather than because the problem solver imposes an unnecessary constraint of keeping lines within the bounds of the square. Only when problem solvers have the capacity to look several moves ahead of themselves will they reach criterion failure sooner, at which point they may realize alternative solutions where some of the lines end outside of the nine dot square. This is another area where individual differences may occur - problem solvers' capacity to "lookahead".

MacGregor and colleagues have demonstrated that their theory can predict the observed behavior of participants in several insight problem solving domains by manipulating the problem to be easier or harder with respect to the theory's predictions. In the nine dot problem, MacGregor and colleagues gave participants the standard nine-dot square but with a line on the solution path already drawn in. Contrary to previous explanations but consistent with their theory, a line extending horizontally across the top three dots and extending outward to a non-dot point showed worse performance than a diagonal line from the top left dot to the bottom right dot. Previous explanations would expect the former to be more of an aid to solving the problem because it removes the "lines have to be within the square" constraint, whereas the model's prediction is that the diagonal line forces alternative solutions to be sought more quickly (because drawing another two lines while keeping lines inside the square would only cross out a maximum of three more dots, whereas the horizontal line means four can be crossed out).

Ormerod, MacGregor, and Chronicle (2002) apply the theory to an eight-coin problem, whereby from an initial configuration of eight coins, two coins must be moved so that each of the eight coins touches three and only three other coins. The insight to the solution involves realizing that coins can be stacked on top of each other (the solution involves two sets of four coins, where each set has three coins touching each other with the final coin on top of the three). In a similar manner to their nine-dot experiments, Ormerod and colleagues show that it is the moves available that governs how quickly alternative solutions are sought. The problem is solved more quickly when there are no initial moves that will bring one coin touching three others than if there are several moves where a coin could be placed to touch three others.

The Representational Change Theory

Knoblich and colleagues (Knoblich, Ohlsson, Haider & Rhenius, 1999; Knoblich, Ohlsson & Raney, 2001) present a different view of why impasse occurs in problem solving, and how it is overcome. For Knoblich et al., the problem solver creates an initial representation of the problem that has a low probability of success. Representation can be thought of as the distribution of activation across pieces of knowledge in memory. The initial representation of the problem means that task knowledge that is not critical for solution becomes active rather than task knowledge that is critical for solution. It is only through altering this representation, and hence altering the activation of task knowledge, that subsequent success will be achieved.

Knoblich et al. argue that the problem solver's initial representation sets unnecessary constraints on their problem solving, and/or creates a representation of the problem which is not rich enough. Their constraint relaxation and chunk decomposition theory states that problems can be re-represented (and therefore impasse overcome) by relaxing the unnecessary constraints that have been placed on the problem, and/or decomposing chunked objects in the representation. Constraint relaxation can be thought of in terms of a decrease in activation of a piece of knowledge that has acted as an unnecessary constraint on the problem. Chunk decomposition means the separation of those objects which can be broken down into further meaningful objects, such as a person's telephone number being decomposed into the individual digits. Both constraint relaxation and chunk decomposition cause a change in the distribution of activation across pieces of knowledge (i. e., a re-representation of the problem).

The theory has different levels of constraint and different levels of chunk. The most difficult constraint to relax is one whose scope covers the whole problem, because if this is the case then the whole problem representation needs to be revised. Local constraints are more likely to be relaxed first because they only affect a portion of the problem representation. In the case of chunks, loose chunks (i. e., chunks which decompose into further chunks) are more likely to be decomposed than tight chunks (i. e., chunks which decompose into entities which are not themselves chunks).

Knoblich and colleagues (Knoblich et al., 1999; Knoblich et al., 2001) have used a matchstick algebra domain to test their predictions. Each problem is a numerical equation written out in Roman numerals using matchsticks, where a single match has to be moved in order to make the equation equal. Predictions based around the types of matchstick problem used confirmed the predictions of their theory, with local constraint problems being solved more quickly than global constraint problems, and loose chunk problems being solved more quickly than tight chunk problems.

Purpose of the Present Study

The two theories outlined above gain support from different domains within insight problem solving. The main support for the representational change theory is from one-step problems. Ohlsson (1992) has applied the theory to the nine dot problem but predictions from the theory are much clearer for the matchstick problem. The main support for the progress monitoring theory is from limited-move problems (in fact, the theory is difficult to apply to single-step domains because it relies on the constant monitoring of progress in the problem). This paper will use a third type of problem domain with which to test the two theories - that of unlimited moves to problem solution.

In all of the empirical work on insight, there is very little literature concerning the operational definition of what constitutes an impasse, other than it is a period of time where the problem solver has difficulty solving the problem. Knoblich et al. (2001) examined impasse based on fixation duration (the time spent looking at the problem, or components of the problem) by dividing each participant's solution time into three equal intervals. Fixation duration increased across consecutive intervals for problems that their theory predicted would be difficult, and did not for problems their theory predicted would be less complex (consistent with the idea that problem solvers spend more time in impasse for more complex insight problems). However, in the experiments covered previously, it was not clear when an impasse had occurred, or for how long the impasse lasted. This is because in the single-step matchstick domain, all problem solving is occurring within the head of the problem solver – the point at which problem solvers move from trying out different solutions to actually becoming stuck in the problem is not clear. In the nine-dot and eight-coin problems, no timing data were recorded, and so there is no way of knowing if problem solvers even encountered an impasse (in fact, the theory would suggest many do not, because they make distance-to-goal reducing moves until realizing failure too late).

Defining what constitutes an impasse within a domain would seem to be critical because this is likely to be when the problem solver is re-representing the problem, so the point at which impasse occurs and the subsequent problem solving behavior following the impasse is where the chief interest lies in insight problem solving. It should be stressed at this point that it is not necessarily the case that insight always follows impasse – an impasse can lead to no insight at all, a partial insight (several of which would be required to achieve proper insight), or complete insight (Ohlsson, 1992).

This article seeks to further the literature regarding insight problem solving in four ways. First, to use an insight problem that is neither single-step nor limited move, but an unlimited move problem. Unlimited move problems have not yet been applied to either of the theories outlined. Second, to test the predictions of the theories outlined when applied to a novel unlimited move problem. Third, to operationalise the term impasse in order to examine both what constitutes an impasse, and to use the evidence (or lack of evidence) of impasse as tests of the theories. Pause length has been examined before in relation to impasse (e. g., Knoblich et al, 2001), but this paper will use a stricter definition of what constitutes an impasse. Fourth, to examine eye movements as well as overt problem moves – eye movement traces have rarely been used in insight problems yet have made successful contributions (e. g., Knoblich et al., 2001). Grant and Spivey (in press) used eye movement data on Duncker’s (1945) radiation problem. They found solvers focused more on the skin area than non-solvers, and when attention was drawn to this area in a second experiment, success rates significantly increased. Eye movement data would therefore seem to be useful in examining insight, and may well provide further evidence for when an impasse occurs.

The Car Park Game

The car park game is a relatively simple problem solving game which is used in children’s mathematics and problem solving, and more recently also exists as a board game (RushHour by Binary Arts). The aim of the game is to maneuver a taxi car out of a car park. The pathway from the taxi car to the exit is obstructed by other cars, and the object is to work out how these cars can be moved away from the exit pathway so that the taxi car is able to leave the car park. The game is illustrated in Figure 1, which shows a simple problem scenario. Cars are moved by clicking the mouse pointer on the front or rear of the car to move the car forwards or backwards, and movement is restricted to the plane that the car is in (i. e., horizontal cars can only move left or right; vertical cars can only move up or down). Clicking the mouse in the center of the car results in the car remaining stationary, as does an attempt to move a car forward/backward when its pathway in that direction is blocked (either by the wall of the car park or by another car). The exit pathway in the problem scenario in Figure 1 can be cleared by moving the rightmost vertical car upward one square, and then moving the horizontal car that blocks the exit pathway rightward.

Insert Figure 1 About Here

The car park game can be seen as bearing a similarity to the eights puzzle (e. g., O'Hara & Payne, 1998) in terms of the type of moves that can be made. The eights puzzle comprises eight tiles numbered 1 to 8 which are represented on a 3-by-3 grid (i. e., one space is left empty). The object of the game is to maneuver the tiles into numerical order by manipulating them using the empty tile space. Another similar problem is the passalong test (Alexander, 1950). This comprises two sets of different colored figures in a square, where the initial state has all the figures of one color on the top part of the square and the figures of the other color on the bottom part of the square. The object is to maneuver the figures in order to reverse their order (i. e., to make the top color figures now be on the bottom, and the bottom color figures now be on the top). Both of these games involve moving objects around an enclosed grid in much the same way as the car park game.

Insight in the Car Park Game

Figure 2 shows a complex problem scenario. At first glance, the main area of complexity of the car park in Figure 2 over the car park in Figure 1 might be thought to be because the car park contains more cars. However, the car park in Figure 2 requires that the taxi be moved <u>before</u> an exit pathway has been created. As we will see later, this presents a major stumbling block in the problem, with the taxi move being the insight that is required to solve the problem. The solution to the problem scenario in Figure 2 is as follows. The topmost car blocking the exit pathway (i. e., the horizontal car immediately below the taxi car) can be cleared by moving the two vertical cars in the top left hand corner upwards as far as possible so that the horizontal car can be moved leftward. The middle car blocking the exit pathway can be cleared by now moving the taxi car downward, enabling the horizontal car in the top right hand corner to be moved leftward such that space is created for the two rightmost vertical cars to both be moved upward. The middle car blocking the exit pathway can then be moved rightward. The bottommost car blocking the exit pathway can be cleared by moving the vertical car in the bottom left hand corner upward, such that the bottommost car can then be moved leftward.

Insert Figure 2 About Here

The car park problem illustrated in Figure 2 is an insight problem where the main difficulty is a failure to consider moving the taxi car until the exit pathway has been cleared. The passalong problem has an insight of similar complexity, where some starting states require that moves be made that initially move the figures <u>away</u> from their final positions (Zamani & Richard, 2000). The difficulty observed on these problems is because of self-imposed constraints or ideas placed on the problem by the problem solver.

The insight car park problem fits in with definitions of insight that have been proposed. For Weisberg (1995), insight must involve a discontinuity (several unsuccessful attempts at a problem followed by the successful solution), and a restructuring of the problem (i. e., simple trial and error should not be sufficient to produce the problem solution). Failure to initially consider the taxi car amongst the possible cars to move will, by definition of the problem, result in initial failure. Several unsuccessful attempts at completing the problem may lead the problem solver to have the insight to realize that the taxi car must be included amongst possible cars to move, at which point the problem can be solved.

The restructuring of the insight car park problem is fairly simplistic yet is similar to the restructuring that occurs in other insight problems considered by Weisberg. The socks problem, for example, involves asking the question “if you have black socks and brown socks in your drawer, mixed in the ratio 4: 5, how many socks would you need to take out to ensure having a pair of the same color?”. The insight here involves moving from a representation of the problem based on mathematics to a representation of the problem based on imagining yourself removing the socks.

A clearer analogous example is the box holding the nails in the Duncker (1945) experiment which needs to be viewed as a shelf rather than as a box. In the insight car park problem, the taxi car has to be viewed in the same way as any of the other cars, and not as a special entity separate from the other cars. The change in representation (and therefore the insight) involves moving from one problem representation where the object in question is constrained in use, to another problem representation where those constraints are relaxed.

<u>Predictions for the Insight Car Park Problem from the Representational Change Theory</u>

The format of the car park game is very simple. The game layout consists of six squares by six squares, and all cars are one square in width and two squares in length. In terms of chunks, the game could not be said to have any chunks that can decompose into smaller entities, so chunk decomposition should not be the source of any problem difficulty. The main constraint in the problem is that cars can only be moved forwards or backwards – this applies to all cars and is stated in the instructions. A secondary constraint which gets imposed on the problem by participants is that the taxi car cannot be moved before an exit pathway has been created. This self-imposed constraint may arise from people's experiences in using taxis (in that they are always the passenger in such vehicles). The constraint concerning the taxi move is the only constraint that can be relaxed in the problem.

The representational change theory would thus predict at least one impasse at some point prior to moving the taxi, a stronger prediction being an impasse immediately prior to moving the taxi (i. e., the insight on the problem should be preceded by one or more impasses). Equally, a failure to solve the problem should not involve a single taxi move because otherwise this is a demonstration of that constraint being relaxed (i. e., while non-solvers may encounter impasse, their impasses must fail to generate the required insight of moving the taxi).

Predictions for the Insight Car Park Problem from the Progress Monitoring Theory

The progress monitoring theory is based on making moves which change the current state of the problem to be as close to the goal state as possible. The main goal in the car park game is to move the taxi car out of the car park, which involves sub-goals of moving other cars away from the exit pathway. Figure 2 shows that there are three cars that block the exit pathway, so reducing the current state of the problem to be close to the goal state involves moving these three cars away from the exit pathway.

The progress monitoring theory employs a lookahead value which determines how many moves ahead people are able to look. In the insight car park problem, moving two of the three cars that block the exit pathway is trivial, after which point the problem solver will realize that the third car is very difficult to move. Therefore anyone with a lookahead of three or more will immediately realize that the problem is more complex than at first one may perceive. A person with a lookahead of two or less will not realize this until clearing the exit pathway of two cars. A person with a lookahead of one will only consider one move at a time, and so will realize the problem difficulty only after moving the second car from the exit pathway. A person with a lookahead of two will also fail to notice the problem's difficulty, because they too will move the first two cars from the exit pathway (it is assumed that problem solvers with a lookahead of two will not re-assess their problem solving after moving one of the cars away from the exit pathway because they will see from the start of the problem that removing two cars is trivial).

Using MacGregor et al. 's (2001) estimates of the distribution of lookahead values, then one can expect 32% of participants to have a lookahead of one, 32% of participants to have a lookahead of two, and 36% of participants to have a lookahead of three. This would mean that 64% of participants should encounter the majority of their impasses between moving the second car away from the exit pathway and moving the third car from the exit pathway. The remaining 36% of participants should encounter the majority of their impasses before moving a single car from the exit pathway.

The progress monitoring theory states that insight (in the form of a search for alternative solutions) is only sought once criterion failure is reached – criterion failure being a failure to reach a minimum distance from the current state to the goal state. This relies on there being a set amount of moves for a problem (in order to calculate a minimum distance that needs to be travelled from the current state). For unlimited move problems, criterion failure under this description will never be reached. This presents an interesting problem for the theory – what happens once problem solvers reach the stage when they realize that moving the third car away from the exit pathway is not trivial? One would expect that the realization of a non-trivial move would cause an impasse, but this may depend on a person's lookahead value and their insight potential (two variables that vary across individuals in the theory). One basic prediction that can be made is that people operating under a lookahead value of three should be more likely to solve the problem and solve it more quickly than people operating under a lookahead of one or two (which are essentially equal for this problem). This is because people with a lookahead of three will realize the difficulty of the problem more quickly. Assigning lookahead values to participants will require the analysis of their behavior in the problem, by examining where impasses occur with respect to how many cars have been moved from the exit pathway.

The progress monitoring theory makes no prediction regarding people who move the taxi and subsequently fail to solve the problem, because the theory does not deal with the relaxation of constraints. The tendency to search for insight is based on criterion failure, which in the insight car park problem amounts to realizing the difficulty of clearing the third car that blocks the exit pathway. Achieving insight will depend on the ability to realize this, combined with insight potential.

Opposing Predictions for the Two Theories

The key to the two theories making alternative predictions is to realize that if the layout of the insight problem remains the same, then the progress monitoring theory predicts that performance on the problem should also remain the same. This is because performance is governed by reducing the difference between the current state of the problem and the final state. The representational change theory on the other hand bases itself around the activation of task relevant and task irrelevant pieces of knowledge, and the re-representation of the problem in order to alter these activations and hence aid solving the problem. Being able to manipulate these while keeping the insight problem constant will therefore provide different predictions to the progress monitoring theory.

Two ways of facilitating insight under the representational change theory would be to suppress the activation of task irrelevant knowledge, and to encourage the re-representation of the problem. The car park game allows both of these to be explored. The general activation of task knowledge should be lower if all of the problems which precede the insight problem are easy as opposed to presenting progressively more difficult preceding problems, because easy problems require less thought and correspondingly should encourage less activation of task knowledge. Similarly, if the insight problem is presented differently to the preceding problems but in a way that remains consistent to its initial layout (e. g., by rotating the problem ninety degrees such that the exit pathway now appears on the right hand side), then re-representation of the problem should be encouraged relative to having the exit pathway in the same location as in all of the preceding problems. Both of these will be manipulated in order to test opposing predictions of the two theories.

The progress monitoring theory would predict no difference on any measure for any of the manipulations, and the representational change theory would predict a difference between the manipulated conditions as opposed to the normal condition. For the representational change theory, the manipulated conditions should facilitate insight, so there should be more solvers in these conditions as opposed to the normal condition (although nothing can be predicted concerning which of the manipulated conditions should fare better). Predictions on other measures, such as the time taken to complete the insight problem, are more difficult to make because although insight should occur more quickly in the manipulated conditions, insight only involves the taxi move. All other moves are likely to be more difficult in the manipulated conditions because the nature of the manipulations are likely to lead to the remainder of the problem being more difficult.

Method

Participants

Thirty nine Psychology undergraduates (11 male, 28 female) participated as part of a participation points scheme. All were naive to the car park game. Participants were randomly assigned to each experimental condition, with 13 in the Normal condition (age range 18-44 years), 13 in the Rotated condition (age range 18-46 years) and 13 in the Easy condition (age range 18-34 years).

Materials

A computer version of the car park game (written in Visual Basic by the author) was used complete with two sets of four practice problems and two types of insight problem. One set of practice problems involved simple problem scenarios only, the optimal number of moves to solution for each successive problem being 6, 6, 6, and 7, with only 1 car ever blocking the exit pathway, and the total number of cars in the car park always being 6. The other set of practice problems involved problem scenarios that were increasingly more difficult, the optimal number of moves to solution for each successive problem being 6, 8, 9, and 10, with the number of cars blocking the exit pathway being 1, 2, 3, and 3 respectively, and the total number of cars in the car park being 6, 9, 9, and 9. None of the practice problems required the taxi car to be moved in order to create an exit pathway. One type of insight problem was the same as that shown in Figure 2. The other type of insight problem was the same as that shown in Figure 2 but the whole problem was rotated ninety degrees such that the exit was now on the right hand side.

The game was presented on a Hitachi Superscan 21" monitor. An ASL4000 eye tracker (accurate to within 1° of the visual angle) with remote floor mounted optics and an EHT tracking mirror were used to record eye movements. Point of gaze data were recorded every 50hz. The data were recorded onto video using a Panasonic AG-7350 VCR with RS232 control. For the purposes of analysis, the eye tracking film was replayed on the same model VCR as it was recorded on. The ASL Eynal programme was used to create the fixation data, and EMAT (developed by University of Derby) was used to map the fixation data onto areas of interest in the insight car park problem.

Design

The independent variable was the problem scenario, with three levels: Normal (four progressively harder practice problems with the standard insight problem as shown in

Figure 2 appearing fifth); rotated (as for the normal condition but the insight problem is rotated ninety degrees such that the exit pathway is to the right); easy (as for the normal condition but the four practice problems are all simple).

The dependent variables were recorded on a move by move basis, and involved both general measures and measures specific to eye movement data. The general measures were the time taken per move, the car moved, and the direction that the car was moved. For the eye movement data, the car park was split into 36 locations (a single location being one of the squares in the basic 6 by 6 car park grid). For each move, the number of times each location was fixated on between each move, and the total fixation time at each location between each move, were recorded. In addition, the number of erroneous clicks of the mouse (e. g., clicking in the center of the car) was recorded.

Procedure

The entire experiment was computer based. Participants were instructed to sit on a stool facing the monitor, resting their chin on a chin rest which was placed 80 centimeters from the monitor. Once comfortable, the participants were informed about the eye tracking equipment and asked to keep their heads as still as possible throughout the experiment. Participants were informed that they could take a break at any time during the experiment. Before running the car park game, participants were shown a calibration screen (a square of nine numbered dots). Calibration involved the participant looking at each dot in turn while the eye tracking equipment was adjusted to track the participants eye movements as well as possible. Re-calibration was carried out if the participant requested a break or they removed their chin from the chin rest.

Once calibration had been achieved, participants were asked to use the mouse with their favored hand, and the car park program was run. Participants were randomly allocated to one of the three experimental conditions. The car park program first displayed a set of instructions which outlined the car park game. The instructions were as follows. <u>You are going to be shown a car park which has cars parked in it. Your task is to get the black taxi car out of the car park so that it can go out and pick up a customer. All cars can be moved forward by clicking on the front part of the car, and backward by clicking on the rear part of the car. Click OK to start!</u>

Once the participant was satisfied that they had understood the instructions, they began the game. Four initial non-insight car park problem scenarios were presented first. Depending on the experimental condition, these either increased in difficulty (normal and rotated conditions) or were all relatively easy to complete (easy condition). The fifth problem scenario was the insight problem, as illustrated in Figure 2. Depending on the experimental condition, this problem was either presented with the exit located in the same position as for all preceding problems (normal and easy conditions) or the whole problem was rotated ninety degrees such that the exit was located to the right (rotated condition).

Due to the eye tracking equipment being relatively uncomfortable, if participants were adamant they could not solve the insight problem they were immediately given a hint ("You have to move the taxi car before you can create an exit pathway").

<u>Data Analysis</u>

For the fixation data, only fixations that lasted longer than 100 ms were used for analysis. The point of gaze data were translated into fixation data by the ASL Eynal programme. The fixation data were then assigned to locations in the insight car park problem using EMAT. The car park area was divided into 36 locations (one per square on the 6-by-6 grid). Each fixation was assigned to a location where possible (fixations landing outside the car park or in between two or more locations were discarded) on a move-by-move basis. This meant that for each move, all of the locations that were fixated on could be obtained, together with the number of fixations in that location and the total time spent fixating in that location.

The eye movement data were not of sufficient quality for 2 of the participants (1 in the normal condition and 1 in the rotated condition). These were not included in any eye movement related analyses.

The way in which an impasse was defined is as follows: A participant has reached impasse for the current move if the fixation time for the move is greater than or equal to the mean fixation time for the participant plus two standard deviations. Under this definition, impasse is sensitive to the individual differences in fixation times across participants. Fixation time is preferred over the time taken per move because it will better reflect the time spent on task (note that using fixation time means that 2 participants will not be included in the impasse analyses because their eye movement data are of insufficient quality).

Results

Practice Problems

The mean number of moves made to solve the practice problems was 14. 15 (3. 99), 12. 90 (3. 22), and 8. 54 (1. 29) in the normal, rotated, and easy conditions respectively. The
mean time to solution for the practice problems was 22. 48 seconds (7. 37), 21. 23 s (10. 40), and 9. 63 s (2. 77) in the normal, rotated, and easy conditions respectively. There
was a main effect of condition for both the number of moves made to solve the practice problems ($F(2, 36)=12.13$, $p<.001$) and the time taken to solution for the practice problems ($F(2, 36)=11.50$, $p<.001$). Post-hoc Bonferroni tests revealed that problems in the easy condition were solved in less moves and in less time than the normal and rotated conditions ($p<.005$ or better in all comparisons).

General Results

There were 31 participants who solved the problem without the need of a hint. There were 8 participants who required the hint in order to solve the problem (6 in the normal condition, 1 in the rotated condition, and 1 in the easy condition). All 8 participants are treated as non-solvers of the problem and remain in all analyses.

The main constraint in the insight car park problem was suggested to be the reluctance in moving the taxi car before the exit pathway had been cleared. This suggests that the taxi move will be more difficult relative to other moves. Figure 3 shows the mean fixation times and the mean move times for the 3 moves preceding the first taxi move, for the taxi move itself, and for the three moves immediately succeeding the first taxi move. A comparison between the average time for the 3 moves preceding the taxi move, the taxi move itself, and the average of the 3 moves succeeding the taxi move showed a main effect for both the time taken per move ($F(2, 76)=7.77$, $p<.005$) and the fixation time per move ($F(2, 72)=7.76$, $p<.005$). Post-hoc comparisons showed significant differences between the taxi move and the preceding and succeeding moves in all cases ($p<.01$ or better in all comparisons). This confirms that the taxi move proves to be a stumbling block in completing the insight car park problem.

Insert Figure 3 About Here

Results Pertinent to the Representational Change Theory

For the purposes of testing out the representational change theory's predictions, all participants will be considered together, rather than in their respective conditions, because it is the point at which impasses occur relative to the first taxi move that is important, rather than whether insight was achieved more quickly in one condition than another.

The first prediction from the representational change theory is that solvers of the problem should encounter impasse before moving the taxi car. Of the 37 participants who could be analyzed under our definition of impasse (i. e., those having eye movement data of a sufficient quality), there were 30 solvers and 7 non-solvers. For the 30 solvers, all encountered impasse before moving the taxi, with 5 encountering impasse immediately prior to moving the taxi. There is also a clear trend in the solvers for the taxi move taking longer relative to other moves - the time spent fixating on the problem was longer for the taxi move than any of the three moves preceding the taxi move or succeeding the taxi move ($F(2, 58)=5.40$, $p<.01$), and the raw time spent on the taxi move was longer also ($F(2, 60)=5.17$, $p<.01$). Post-hoc Bonferroni tests revealed the taxi move to take significantly longer than the three moves preceding and succeeding the taxi move ($p<.05$ or better in all comparisons).

All of the non-solvers encountered at least 1 impasse before being given the hint, but unlike the solvers, they did not achieve the subsequent insight from the impasse and thus needed a hint to solve the problem.

The second prediction from the representational change theory is that non-solvers of the problem should not move the taxi car until after receiving the hint. In total, there were 8 non-solvers of the problem. Of these, 3 did not move the taxi from its original position before the hint, leaving 5 who move the taxi yet fail to solve the problem. These 5 move the taxi an average of 2. 00 times each, yet on each occasion the taxi was always returned to its original position. Why should the problem not be solved once participants have relaxed the constraint of not moving the taxi? Realizing the significance of moving the taxi involves also realizing that the right hand block of cars need to be moved in order to create space for a car to be moved from the exit pathway. In this case, any impasse that precedes a taxi move should examine the right hand area of the car park (the rightmost 12 locations involving two horizontal cars sandwiched by two vertical ones). If non-solvers are moving the taxi as part of some other goal, then it would make sense that they do not fixate on this area often during the nearest impasse that precedes a taxi move, whereas solvers should fixate on this area relatively often.

The fixation data for the nearest impasse that preceded a taxi move (each taxi move where the taxi is in its topmost position; fixation data for the 37 relevant participants) shows that there is a significant difference in the proportion of fixations made in the rightmost area between solvers and non-solvers (for solvers, 24% of their fixations examine the rightmost twelve locations, 9% for non-solvers; $\underline{F}(1, 39)=6.50$, $\underline{p}<.05$). The difference in the proportion of time spent fixating on the rightmost area during the impasse is also significant (for solvers, 19% of the fixation time is spent on the rightmost area, 8% for non-solvers; $\underline{F}(1, 39)=5.56$, $\underline{p}<.05$).

The predictions from the representational change theory would seem to be supported in general. Solvers all encounter impasse before moving the taxi. For non-solvers, almost half fail to move the taxi before being given a hint, with the results suggesting that the remainder may well be moving the taxi as part of a sub-goal whereby the significance of moving the taxi is not noticed.

Results Pertinent to the Progress Monitoring Theory Predictions

For the purposes of testing out the progress monitoring theory's predictions, all 39 participants will be considered together, because what is of interest is the relative number of impasses which occur as each car is moved away from the exit pathway, rather than whether insight was achieved more quickly in one condition than another.

Note that the number of cars moved from the exit pathway only includes the original cars that blocked the exit pathway – for example, if a different car was moved to now be blocking the pathway, this would not count as another car blocking the pathway. This is because it is assumed that the extra car has been moved in order to facilitate the maneuvering of other cars.

There are three keys areas for impasse: impasses occurring before the first car is moved from the exit pathway, impasses occurring between moving the first and second cars from the exit pathway, and impasses occurring between moving the second and third cars from the exit pathway (no impasses occur outside of these key areas). By examining where the majority of impasses lie with respect to how many cars have been moved from the exit pathway, participants can be assigned to lookahead values.

MacGregor et al. (2001) predict that 64% of participants will have the majority of their impasses between moving the second car and third car out of the exit pathway (i. e., employing a lookahead of one or two). The remaining 36% of participants will have the majority of their impasses before moving the first car out of the exit pathway (i. e., employing a lookahead of three).

Let us consider how to measure which of the three key areas for impasse has the majority of impasses. There are two ways to look at impasse: the number of impasses and the time spent in impasse. There are also two ways in which to measure where the majority lies: the majority being the area which has more impasse than either of the other two areas, or the majority being the area which has more impasse than the sum of the impasse in the other two areas. This results in four definitions of the "majority of impasses". Table 1 shows the distribution of lookahead values for each definition of majority of impasses.

Insert Table 1 About Here

Participants who have a lookahead of one or two should have the majority of their impasses between moving the second and third cars from the exit pathway. Participants who have a lookahead of three should have the majority of their impasses before moving the first car from the exit pathway. Very few participants should have the majority of their impasses occurring between moving the first and second cars.

When trying to assign participants to lookahead values, it is clear that the raw number of impasses is not a sufficient method – the values do not support MacGregor et al. 's predictions. There are roughly an equal amount of participants assigned to lookahead values one and two, and to lookahead value three, whereas it was predicted there would be a 64%/36% split. However, when considering the time spent in impasse, the figures are much closer to the predictions, with 20 participants (54%) assigned to lookahead one or two, and 11 participants (30%) assigned to lookahead three. Across all definitions, there are very few participants who have the majority of their impasses between moving the first and second cars, as predicted by the progress monitoring theory.

The time spent in impasse is the better predictor of how many participants should be assigned to each lookahead value. Existing studies of eye movements in insight (none of which measure raw number of impasses) have used fixation duration as a measure of impasse (e. g., Knoblich et al., 2001; Grant & Spivey, in press). Time spent in impasse will therefore be used in examining MacGregor et al. 's predictions, and the fact that the raw number of impasses in not a good measure will be returned to in the discussion section.

The figures in column 3 of Table 1 represent the best match to MacGregor et al's predictions and it will be these that are used in examining the difference in performance between participants with a lookahead of one or two, and those with a lookahead of three. Table 2 shows the performance of participants assigned to each lookahead value. It is clear that the data support the predictions of the progress monitoring theory: Performance for participants with a lookahead of three is far better than that of participants having a lookahead of one or two, in terms of the time taken to solution, the number of moves made to solution, and the number of participants able to solve the problem. A comparison of the solvers shows that those assigned a lookahead value of three complete the problem more quickly ($F(1, 23)=26.81$, $p<.001$) and complete the problem in fewer moves ($F(1, 23)=10.94$, $p<.01$), as predicted by the progress monitoring theory. The non-solvers are not included in any time/move analyses because their inclusion will skew results, especially since only participants who were assigned a lookahead value of one or two fail to solve the problem.

Insert Table 2 About Here

Results Pertinent to Opposing Predictions of the Two Theories

The representational change theory predicts that the insight problem will be solved more often in the easy and rotated conditions relative to the normal condition, whereas the progress monitoring theory predicts no difference in performance across all conditions. Table 3 shows the performance measures for each condition. The number of erroneous clicks on cars (e. g., clicking in the center of the car, or trying to move a car forward or backward when that direction is either blocked by the car park wall or by another car) is included because it is a measure of task difficulty. Erroneous clicks signify frustration with the task – all participants should be fluent in moving cars because they solved four problems before attempting the insight problem.

Insert Table 3 About Here

Table 3 shows a clear trend towards better performance in the rotated and easy conditions. To ease statistical examination, the rotated and easy conditions will be collapsed into one (the representational change theory only makes the prediction that there will be a difference between the normal and rotated/easy conditions). There is a significant difference between the normal and rotated/easy conditions for the number of solvers (Fisher's Exact, $\underline{p}$=0. 01) and for the number of erroneous clicks ($\underline{U}$=76. 00, N=39,

$p < .01$) that are made. However, there is no difference between the solvers in the normal and rotated/easy conditions for the number of moves to solution ($F(1, 29) = 1.56$, $p > .05$) or
for the time taken to solution ($F(1, 29) = 1.90$, $p > .05$).

These data provide strong support for the representational change theory's prediction that there will be a difference in success rates between the normal and rotated/easy conditions. Participants in the normal condition show a higher degree of failure (i. e., the need for a hint in order to solve the problem) and show a higher degree of frustration (the majority of participants making erroneous clicks of the mouse, presumably out of frustration). The number of moves and the time taken in completing the task are less clear in providing any support for either theory.

Discussion

The car park problem solving task has shown support for both of the theories outlined in this paper. For the representational change theory, the prediction that those who solved the problem will encounter impasse before the critical problem move (moving the taxi) is strongly supported, and the prediction that non-solvers will fail to move the taxi is weakly supported (with the suggestion that those non-solvers who moved the taxi did so as part of a sub-goal which did not involve the critical right hand side cars). For the progress monitoring theory, the prediction that those who use a lookahead of three will perform better than those with a lookahead of one or two is strongly supported. People with a lookahead of three encounter impasse more quickly and therefore achieve insight more quickly.

In terms of the opposing predictions of the two theories, the representational change theory's predictions are better supported than those of the progress monitoring theory, with problem solvers being more successful on the insight problem when given easy practice problems or when given a rotated version of the insight problem. Insight in the representational change theory is the re-representation of a problem in order to alter the activation of task knowledge (to make task relevant knowledge more active). In the easy condition, insight was facilitated by using simple practice problems such that the opportunity for irrelevant task knowledge to become active was minimal. In the rotated condition, the exit was rotated ninety degrees so that it now appeared on the right hand side of the car park. Insight was facilitated by encouraging participant's to re-represent the problem because of a complete alteration of the problem scenario to what they had previously been exposed to. Neither of the manipulations sought to explicitly try and relax the taxi-move constraint – they merely sought to encourage its relaxation by altering other aspects of the representation of the insight problem.

In intuitive general problem solving terms, both of the manipulations made should mean that the problem solver has more difficulty in solving the problem. Giving only easy practice problems sets up the problem solver to expect a full set of easy problems, so when they encounter the insight problem they should have more difficulty than those in the normal condition who have encountered successively harder problems and from this experience should be more adept at solving the insight problem. This is because the prior experience of only simple problems should mean that problem solvers are less exposed to the types of correct operators (i. e., moves) that should be applied to the problem (e. g., Lovett and Anderson, 1996). Those encountering the rotated insight problem should similarly be disadvantaged because now suddenly the nature of the problem has changed against what the participant was expecting.

The counter-intuitive results may also be expected to be shown for the time taken and moves made to solution. However, the results were less clear for these measures, and this is not surprising because the car park problem is an unlimited move problem. The insight in the problem only affects the taxi move, with all other moves unaffected. The other moves should be more difficult to make in the manipulated conditions relative to the normal condition. For example, in the easy condition, the fact that participants had much less exposure to the car park game prior to the insight problem (their practice problems are completed much more quickly than the other conditions, see practice problems section) is likely to hinder their general car park problem solving performance even though it results in facilitating insight.

The representational change theory predicts improved success rates in the easy and rotated conditions as compared to the normal condition, which is the exact opposite to what would intuitively be expected. This is an important finding and one that needs to be explored further. Primarily, it enables the activation of problem knowledge (as manipulated in the easy condition) and the re-representing of a problem (as manipulated in the rotated condition) to be compared in terms of how they affect performance.

The testing of the predictions of the two theories has hinged upon the operationalisation of the term impasse: An impasse was defined within the scope of the problem as being when the fixation time for the current move was greater than or equal to the mean fixation time for the participant plus two standard deviations. This definition served to support both of the theories outlined.

When assigning lookahead values in the progress monitoring theory, both the raw number of impasses and the time spent in impasse were used. The raw number of impasses did not serve as a good predictor of lookahead values, whereas the time spent in impasse provided a good match to the predicted ratios of lookahead values. The time spent in impasse has also been used to examine insight in the past (e. g., Knoblich et al., 2001). Given that insight does not always follow impasse, it would make sense that insight is more likely to occur when the problem solver spends more time in impasse.

The definition of insight that has been used in this paper therefore specifies a minimum cut-off point for a pause in problem solving to be considered an impasse, and it is the time spent in these impasses that is the important factor, and not the raw number of impasses. This is consistent with previous literature concerning what occurs during an impasse. The Gestalt psychologists (e. g., Kohler, 1969) proposed that productive thinking, or thinking about the problem in a different way, occurs during impasse.

Subsequent insight would mean that the problem solver has restructured the problem in a way that can result in its solution.

Schooler, Ohlsson, and Brooks (1993) suggest that impasse might involve, amongst other things, the spreading activation of memory elements that are important in the problem. The activation of memory elements that are not important in solving the problem need to decay and allow those memory elements that are important to become active. This change in activation must be an unconscious process because they find that verbalisation leads to poorer performance on insight problems. In addition, participants are not able to guess how close they are to obtaining the solutions of insight problems, which is not the case for non-insight problems (Metcalfe & Wiebe, 1987).

Kaplan and Simon (1990) on the other hand suggest that what occurs during an impasse is a search for an appropriate heuristic (a rule of thumb which can be used to constrain the problem so as to reduce the search for the solution) within a problem space (Newell & Simon, 1972). They show that hints serve to constrain the problem space and therefore help the problem solver to find the appropriate heuristic to solve the problem.

All of the above hypotheses concerning what occurs in the problem solver's mind during impasse would suggest that the longer the duration of an impasse, the more the likelihood of subsequent insight being achieved. What has been done here is the provision of a systematic method of classifying when a person encounters an impasse. Defining impasse in workable terms has rarely been attempted before. The results here have shown that being able to identify when impasses are occurring helps in testing theories of insight. In addition, it will help in examining impasse. Once it is known when an impasse is occurring, the type of behavior that occurs during impasse and immediately after impasse can be analyzed and compared to behavior that occurs in the absence of impasse.

The research here also provides a case for the merging of the two theories outlined, partly because the descriptions of each theory deal with different areas of insight, and partly because they each make distinctly different predictions that are nevertheless supported in the insight car park problem. The progress monitoring theory essentially covers insight up to the point at which insight is sought. MacGregor et al. (2001) consider that insight might involve the discovery of novel moves which can be stored as promising states, but this hypothesis is not expanded into a theory of how insight occurs. The progress monitoring theory is able to predict, based on the task at hand, when participants are most likely to seek alternative solutions and hence when participants will seek insight. The representational change theory on the other hand covers how insight will be achieved, and therefore the point at which insight is sought is the beginning point of the theory.

The results presented illustrate how the theories can be merged with regard to when alternative solutions (i. e., insight) are considered. For the solvers, assuming their impasse leads to subsequent insight, a strict version of the representational change theory predicts that the impasse should occur immediately prior to moving the taxi. On the other hand, the progress monitoring theory predicts that the location of the impasse will be determined by lookahead. If a participant has a lookahead of three, then they should impasse early on in the problem. In contrast, a participant with a lookahead of one should impasse later on in the problem. The progress monitoring theory's predictions were supported in the results presented. This clearly shows the benefits of merging the two theories – the progress monitoring theory provides an explanation of why some people will not show impasse immediately prior to the solution move as predicted by the representational change theory. Obviously the bridging point between the two needs further specification, but providing an integrative theory of insight which encapsulates both of the theories covered here would seem to be the way forward in insight research.

This paper has tested two theories of insight using a problem solving task in which neither theory has previously been applied: A problem where there are unlimited moves to solution. It showed that predictions could be made from both theories regarding problem performance, and those predictions were borne out by the data. The notion of impasse was able to be defined in realizable terms which was then used to test the predictions made by the theories. The data provided support, albeit not unequivocal, for the representational change theory when examining opposing predictions from the theories, and this area is one which needs examining further. The results here have shown that the use of eye movement data (in terms of providing a source of definition for impasse) could be an important area in insight research, and that theories of insight can be applied to problems outside of those which the theories were designed to explain. Further research needs to examine impasse further by considering the merging of the two theories described, and by comparing problem solving behavior pre- and post-impasse in order to examine further the factors which influence how quickly insight is achieved.

References

Alexander, W. P. (1950). Une échelle de performance pour la mesure de l'intelligence pratique [A performance scale for the measurement of practical intelligence]. Paris, France: C. P. A.

Burnham, C. A., & Davis, K. G. (1969). The nine-dot problem: Beyond perceptual organisation. Psychonomic Science, 17, 321-323.

Duncker, K. (1945). On problem solving. Psychological Monographs, 58, 1-113.

Grant, E. R., & Spivey, M. J. (in press). Eye movements and problem solving: Guiding attention guides thought. Psychological Science.

Kaplan, C. A., & Simon, H. A. (1990). In search of insight. Cognitive Psychology, 22, 374-419.

Kohler, W. (1969). The task of Gestalt psychology. Princeton, NJ: Princeton University Press.

Knoblich, G., Ohlsson, S., Haider, H., & Rhenius, D. (1999). Constraint relaxation and chunk decomposition in insight problem solving. Journal of Experimental Psychology: Learning, Memory, and Cognition, 25, 1534-1555.

Knoblich, G., Ohlsson, S., & Raney, G. E. (2001). An eye movement study of insight problem solving. Memory & Cognition, 29, 1000-1009.

Lovett, M. C. & Anderson, J. R. (1996). History of success and current context in problem solving: Combined influences on operator selection. Cognitive Psychology, 31, 168-217.

MacGregor, J. N., Ormerod, T. C., & Chronicle, E. P. (2001). Information processing and insight: A process model of performance on the nine-dot and related problems. Journal of Experimental Psychology: Learning, Memory, and Cognition, 27, 176-201.

Maier, N. R. F. (1931). Reasoning in humans: II. The solution of a problem and its appearance in consciousness. Journal of Comparative Psychology, 12, 181-194.

Metcalfe, J., & Wiebe, D. (1987). Intuition in insight and noninsight problem solving. Memory and Cognition, 15, 238-246.

Newell, A. & Simon, H. A. (1972). Human problem solving. Englewood Cliffs, NJ: Prentice-Hall.

O'Hara, K. P, & Payne, S. J. (1998). The effects of operator implementation cost on

planfulness of problem solving and learning. Cognitive Psychology, 35, 34-70.

Ohlsson, S. (1992). Information processing explanations of insight and related phenomena. In M. T. Keane & K. J. Gilhooly (Eds.), Advances in the psychology of thinking (pp. 1-44). London, UK: Harvester-Wheatsheaf.

Ormerod, T. C., MacGregor, J. N., & Chronicle, E. P. (2002). Dynamics and constraints in insight problem solving. Journal of Experimental Psychology: Learning, Memory, and Cognition, 28, 791-799.

Scheerer, M. (1963). Problem solving. Scientific American, 208, 118-128.

Schooler, J. W., Ohlsson, S., & Brooks, K. (1993). Thoughts beyond words: When language overshadows insight. Journal of Experimental Psychology: General, 122, 166-183.

Weisberg, R. W. (1995). Prolegomena to theories of insight in problem solving: A taxonomy of problems. In R. J. Sternberg & J. E. Davidson (Eds.), The Nature of Insight (pp. 157-196). Cambridge, MA: MIT Press.

Weisberg, R. W., & Alba, J. W. (1981). An examination of the alleged role of “fixation” in the solution of several “insight” problems. Journal of Experimental Psychology: General, 110, 169-192.

Zamani, M. & Richard, J. -F. (2000). Object encoding, goal similarity, and analogical transfer. Memory and Cognition, 28, 873-886.

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Table 1

Key Areas where the Majority of Impasses Lie for the Four Definitions of "Majority of Impasses".

	Number of impasses		Time spent in impasse	
Key area where majority of impasses lie	Greater than either of other 2 areas	Greater than sum of other two areas	Greater than either of other 2 areas	Greater than sum of other two areas
Before first car moved	9	9	11	11
Between first and second cars	4	4	6	6
Between second and third cars	11	13	20	20
No specific area	13	11	0	0

Table 2

Performance of Participants when Assigned to Lookahead Values of One/Two, or Three.

	Lookahead one/two	Lookahead three
Solvers	14	11
Non-solvers	6	0
Moves to solution (solvers only)	37. 14 (18. 79)	21. 36 (5. 14)
Time to solution (solvers only)	92. 29 s (43. 33)	42. 73 s (11. 45)

Table 3

Car Park Performance Across the Three Experimental Conditions.

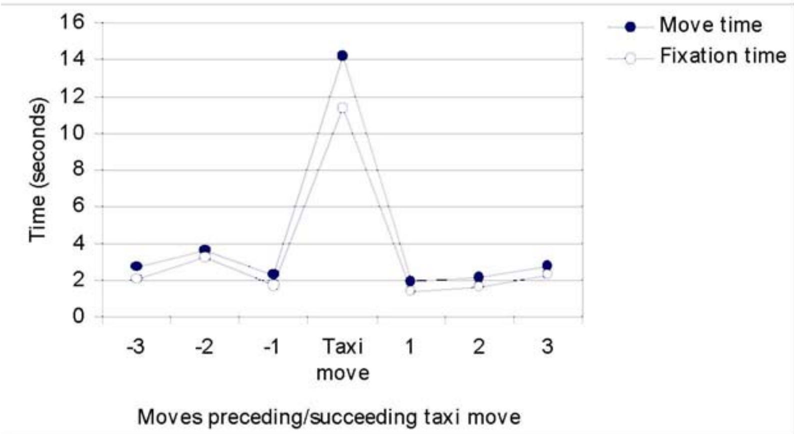
	Condition		
	Normal	Rotated	Easy
Solvers	7	12	12
Non-solvers	6	1	1
Participants making erroneous clicks	9	3	2
Number of erroneous clicks	5. 31 (9. 11)	0. 31 (0. 63)	0. 38 (0. 96)
Moves to solution (solvers only)	23. 00 (7. 57)	32. 58 (17. 88)	29. 33 (14. 90)
Time to solution (solvers only)	53. 43 s (22. 00)	95. 83 s (49. 77)	59. 00 s (28. 95)

Figure Captions

Figure 1. A Simple Car Park Problem.

Figure 2. The Insight Car Park Problem.

Figure 3. Mean Fixation Time and Mean Move Time for the First Taxi Car Move, and the Three Moves Preceding and Succeeding the First Taxi Move.


Move time
Fixation time
Time (seconds)
16
14
12
10
8
6
4
2
0
-3
-2
-1
Taxi move
1
2
3
Moves preceding/succeeding taxi move