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Inducing Absent-Mindedness in the Lab

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Inducing Absent-Mindedness in the Lab†

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Abstract: After years of neglect, Piccione and Rubinstein (1997a) re-examined the problem of imperfect recall and its implications for game theory. They introduced the notion of absent-mindedness through a decision-making problem called the absent-minded driver's paradox. This simple game precipitated a vigorous discussion with different researchers having strong opinions about whether the paradox actually exists. Alternative interpretations and varied ways to resolve the paradox were suggested. In the hopes of forwarding this debate, we provide a technique to directly test absent-mindedness in the laboratory, even though in the past it has been claimed to be impossible to achieve absent-mindedness in a controlled environment. To accomplish this we rely on a technique called divided attention to impair a subject's recollection of previous choices. Our findings indicate that subjects in the experiment suffer from absent-mindedness while still behaving in a rational manner. Our experimental data for the absent-minded driver's game shows that a substantial number of subjects demonstrate behavior consistent with the paradox.

Keywords: Imperfect recall, Absent-minded driver's paradox, Experiments

JEL Classification: C72, C91

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I. INTRODUCTION

In an interesting paper Piccione and Rubinstein (1997a) set out to catalog the numerous difficulties and interesting questions involved in modeling games with imperfect recall. Their paper appropriately titled "On the Interpretation of Games with Imperfect Recall" stirred up a veritable hornet's nest culminating with a special issue of *Games and Economic Behavior* being devoted to the topic (Volume 20, 1997). Their contention was that many concepts and techniques that form the core of contemporary game theory and decision theory could be problematic in the presence of imperfect recall. Applying standard modeling principles to games of imperfect recall leads to situations fraught with ambiguities raising a host of interpretational issues.

The most interesting contribution of their paper is a rather simple but stimulating decision-making problem called the Absent-Minded Driver paradox. In this problem the paradox arises simply because the decision-maker forgets his own past actions. Formally, absent-mindedness is a specific type of imperfect recall where the agent is unable to distinguish between two histories on the same path. Hence the agent can take an action that leads back to the same information set making it impossible to distinguish between subsequent actions. The bulk of the responses to Piccione and Rubinstein's (1997a) were attempts to resolve the paradox of the absent-minded driver with the exception of Aumann, Hart and Perry (1997b), who resorted to a forgetful passenger as well to address the same issue.

The tale of the absent-minded driver goes as follows. Consider a driver sitting at his favorite bar late one night trying to determine the best way to get home. He knows that the first exit will lead to the bad part of town giving him a payoff of zero. The second exit takes him home where he gets a payoff of four. If he continues past the second exit then he can stay at a highway motel, which is not all that bad giving him a payoff of one. Unfortunately, the driver is absent-minded: *he knows that he cannot distinguish between the two exits.* While sitting at the bar, the driver must decide whether he will exit or not when he is at an intersection. Allowing for pure strategies only, and given that he cannot distinguish between the two exits his optimal decision would be to stay on the road and spend a night at the motel earning a payoff of one. However, in the process of executing this pure strategy, once he is on the road and arrives at an intersection, he believes there is a 50% chance that it is the first exit. Computing his expected payoff he finds that his payoff from exiting is: $0.5(4) + 0.5(0) = 2$. This is better than his payoff from staying at the motel implying that that he should exit. In other words, the decision maker would like to revise his initial plan once he reaches an exit despite the fact that there is no new information. Thus we now have a paradoxical situation where the driver's behavior is time inconsistent. Observe that this is not a standard time inconsistency example, since the decision maker is altering his initial plan even in the absence of new information or any change in preferences.

Note that absent-mindedness in terms of the example stems from the fact that the driver may have chosen to continue past Exit 1, but cannot remember this and is thus unable to distinguish between Exits 1 and 2. Moreover, in the story the driver is aware that he is absent-minded and takes this into account. Thus the immediate problem that Piccione and Rubinstein highlight is that there seems to be a paradox between what the driver wishes to do in the *planning stage* and at the *action stage*. This toy example in the words of Bart Lipman (1997) "*touched a nerve*."

Without going into details we now provide a quick summary of relevant papers. Aumann, Hart and Perry (1997a) assume that there is a preplay planning stage and argue in favor of the modified multiselves approach (where a player is viewed as consisting of different temporal selves). They assume that the driver must make a decision at each exit he comes to, but can only control his actions at the current exit. Gilboa (1997) does not allow for a planning stage and assumes that the decision maker has no control beyond the situation in which he acts. This is essentially a team approach similar to Von Nuemann and Morgenstern's (1944) notion of bridge being a two-player game. Lipman (1997) shows that Gilboa's model is equivalent to Aumann, Hart and Perry (1997a) because in the end they do precisely the same calculations. Other discussions of the paradox may be found in Battigalli (1997), Grove and Halpern (1997), Halpern (1997), Aumann, Hart and Perry (1997b), and more recently in Board (2003).[1]

Despite these different responses, there still is no clear theoretical consensus on resolving the problem of the absent-minded driver. To sum up in the words of Piccione and Rubinstein (1997b) "*…it is not surprising that the paradox disappears when interpretative ambiguities are removed by making specific assumptions.*" We believe that such a conclusion serves to highlight the fact that more research is needed on this topic to ascertain what the appropriate assumptions are. It is in this context that we believe experimental testing will help us better determine how decision makers behave when they are absent-minded. The real challenge of course lies in being able to devise a direct test of absent-minded behavior. To actually test absent-mindedness, one must ensure that the subjects do not remember what actions they have previously taken, or even that they have taken an action. Once it can be shown that the subjects do indeed have imperfect recall, the next step would be to test whether they get caught in the paradox of the absent-minded driver.

Huck and Muller (2002) were the first to test the absent-minded driver in the laboratory. They argue that narcotizing subjects would perhaps enable a direct test of absent-mindedness.[2] Unwilling to pursue such radical techniques, Huck and Muller (2002) instead test Gilboa's (1997) alternative specification of the problem. In this formulation, there are two players constituting a team who receive identical payoffs at every terminus of the game. One player in the team makes the Exit 1 decision, and the other player makes the Exit 2 decision. Players are randomly assigned roles and have to make their decision without knowing their role. Also, when called upon to act, they do not know if the other player has already made a decision. One should be cautious when extrapolating these results to the more general absent-mindedness problem as the experimental design introduces a confounding factor, a second person. Consequently, when making the decision to exit players are not only taking a risk with their own payoff,

[1] Piccione and Rubinstein (1997b) wrote a second paper in which they summarize and respond to all the responses to their paper.

[2] Other possible suggested alternatives for inducing absentmindedness include hypnosis or a series of swift blows to the head.

but with the payoff of someone else as well. By now there is a large literature documenting that people are not solely interested in their own material well being.[3] Further, recent work by Cooper and Van Huyck (2003) suggests that subjects have a preference to afford other people the opportunity to make decisions in an experiment. Such a preference would lead to an underestimate of the desire to exit in the experiments of Huck and Muller (2002). This question is not fully resolved in their paper. They consider two treatments: in one subjects are randomly paired with each other, and in the other they repeatedly interact with the same person. In the first treatment, behavior approximates the mixed strategy equilibrium of the game. In the latter case, they find that subjects co-ordinate either on the (exit, stay) or the (stay, exit) pure strategy equilibrium.

In this paper we devise a procedure to induce absent-mindedness in the lab, that is make subjects forget their own past decisions. This permits us conduct a direct test of the absent-minded driver problem, thus avoiding potential confounds. To test the original version of the absent-minded driver story and identify empirical regularities about absent-minded behavior using controlled laboratory experiments, we utilize a technique called *divided attention* (see for instance Deutsch and Deutsch (1963); Allanport, Antonis and Reynolds (1972); Kahneman (1973)) put forth by psychologists. The basic notion is straightforward: when people are focusing on multiple stimuli, their memory response performance deteriorates.[4] The existence of the distraction lowers a respondent's ability to recall information, identify patterns, etc. (see Ducan 1980, Hirst 1986 for reviews). Tests of memory recall can be either free response where the subjects is asked an open ended question about what they remember, or can be cued by the experimenter asking a directed question such as "Did you see ___?". When compared with subjects giving a stimulus their full attention, subjects who divide their attention between multiple stimuli have poorer free and cued recall (Murdock 1965, Baddeley, Lewis, Eldridge, and Thompson 1984, Naveh-Benjamin, Craik, Guez and Dori 1998). Interestingly, the

[3] See Kagel and Roth for a survey (1995). The classic example is the dictator game, where one player has to decide how to allocate some fixed amount of money between herself and another person. In laboratory studies, most people do not keep all of the money even in one-shot games (see Güth, Schmittberger, and Schwarze 1982, Hoffman, McCabe, Shachat, and Smith 1992, and Cox and Deck 2005).

[4] Kahneman's (1973) model of divided attention is probably one that would appeal most to economists. He argues that our cognitive capacities are limited and attention allocates these limited resources to various tasks. Hence as the number of tasks increases, performance declines.

impact on performance is similar when the stimuli are received by the same sense, or through different senses (see Bonnel, Stein, and Bertucci 1992 and Bonnel and Hafter 1998). This memory reduction is not due simply to subjects spending less time processing information from a particular stimulus when their attention is divided (Naveh-Benjamin, Craik, Gavrilescu and Anderson 2000) or by degrading associative process (Naveh-Benjanmin, Guez, and Marom 2003). In fact recent studies show that the brain actually process information differently when attention is divided (Anderson, Iidaka, Cabeza, Kapur, McIntosh, and Craik 2000 and Iidaka, Anderson, Kapur, Cabeza, and Craik 2000). Thus, it is possible to present a person with information that they cannot remember even though they can respond to it.

In the next section of the paper we discuss how we use divided attention to induce absent-mindedness in the laboratory. Section 3 discusses our experimental results and Section 4 has some concluding remarks.

II. Experimental Design

To explore the absent-minded driver problem specifically and absent-mindedness more generally we conducted a series of single person computerized experiments. Unlike many controlled experiments, in which subjects make decisions in a quiet computer lab, these experiments were intentionally conducted in more animated areas, such as the student union, so as to contribute to the distractions faced by subjects. To allow for this flexibility, the experiments were computerized using handheld devices.[5] Undergraduate students at the University of Arkansas were approached by a researcher about participating in an economics experiment lasting 10-15 minutes.[6] Participants first read the two page written instructions and then completed a comprehension quiz. Copies of the directions and the quiz can be found in the Appendix. After their responses to the quiz were reviewed, subjects began the experiment.[7]

[5] A copy of the program is available from the authors upon request. However, this program is targeted for the Windows CE operating system.

[6] Some people who had participated in previous unrelated experiments were sent e-mail telling them where the experimenters would be conducted at a particular time and date.

[7] Anyone unfamiliar with the use of a handheld device or a stylus went through an introductory program before going on to the experiment.

The experiment involved three phases; a 30 period decision phase, a 16 period memory test, and a four period programming phase. Subjects did not know the duration of any phase of the experiment. At the end of the experiment, subjects drew a ball from a bingo cage to determine which decision period would be included in their payoff and rolled a four sided die to select a programming period for payment. Subjects were paid for every period in the memory test. The average payoff was $12.85 including a $2.50 participation fee. Each subject was paid privately.

EXPERIMENT PHASES

The first phase is the *decision phase* which is designed to examine sequential behavior with absent-mindedness. In the decision phase, the subjects faced two tasks in every five second period.[8] One was the "map" task corresponding to the action stage discussed above, and the other was a letter matching task that served as a distracter.[9] The left-hand panel of Figure 1 shows the screen of a subject in the decision phase.[10] On this map the first exit has a payoff of $2, the second exit has a payoff of $0 and the end of the road has a payoff of $1. For simplicity we refer to this map by the triple (2,0,1).

To determine what a subject chose to do for a specific map, subjects were shown each map exactly twice during the decision phase. However, they did not see that same map in consecutive periods. The first time a subject observed the map the decision applied to the first exit, and the second time the map was observed the decision applied to

[8] Pilot studies were run with period lengths of 4, 5 and 6 seconds. From informal subject debriefing and examining the frequency of non-responses, 5 seconds was determined to be an adequate period length for subjects to make decisions. The downside to a longer time length is that it allows a subject to concentrate on trying to remember a specific map and reducing the impact of divided attention.

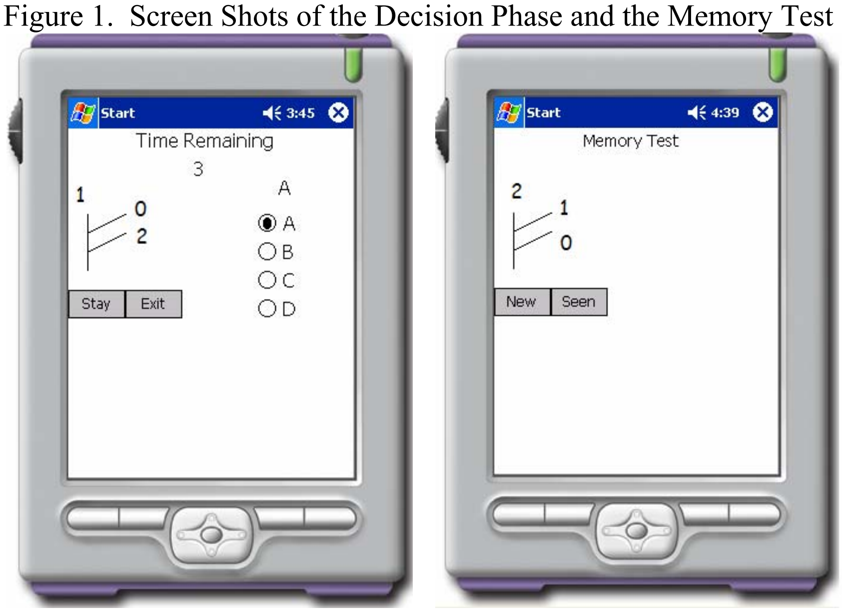
[9] In many experiments, researchers correctly use neutral language and decision contexts. Hoffman et al. (1994) demonstrate how such design features can impact behavior. However, in this case framing the decision as one faced by a driver seems innocuous and we believe aides subjects in understanding the task. Thus, decision trees were referred to as "maps" and subjects were asked to "stay" on the highway or "exit."

[10] This image was used in the directions. Subjects did not observe maps that had a $0 payoff, instead the payoffs all ranged from $1 to $5. Restricting the payoffs to theses five numbers was designed to make it more difficult for subjects to recall specific maps. $0 payoffs were used in the directions so that there would be no ambiguity in the second phase (memory test), as to when the subjects had seen a map.

the second exit.[11] Putting the two choices together in order determined what payoff a subject earned on a particular map.

For the letter matching task, subjects were shown a letter, either A, B, C, or D, and asked to select the same letter from the corresponding list. Subjects received $0.10 for every letter that was correctly matched by the end of the period. Subjects were not informed of the number of periods, but the expected payoff from the two tasks was roughly equal. The comparable payoffs are designed to have subjects split their attention equally between the tasks. In non-salient psychology experiments, subjects are directed to pay attention to both stimuli. For example, Bonnel and Hafter (1998, p.182) instructed subjects to "allocate 80% of attention to A[udio] and 20% to V[isual]."

Figure 1. Screen Shots of the Decision Phase and the Memory Test



The second phase of the experiment was a cued recall *memory test*. Over the course of 16 un-timed periods, subjects were shown 16 maps and asked to identify which ones they had "seen" in the decision phase and which ones were "new." The right hand panel of Figure 1 shows the screen for a subject in the memory test. Eight of the maps

[11] Subjects were required to make a decision on the map a second time even if they selected exit the first time they observed the map. This ensured that the experiment length and number of times subjects observed any particular map were identical across subjects. It is also potentially important for the second phase of the experiment, the memory test, as seeing the same map twice should improve one's recall.

were randomly chosen from among the 15 subjects had observed in the decision phase. The other 8 maps were new. Subjects were paid $0.25 for every correct answer. Subjects were fully informed about the existence of the memory test before they began the decision phase, which increases the incentive to remember maps in the decision phase beyond just the payoffs for that phase.

The final phase of the experiments corresponds to the *planning stage* discussed earlier. Here, subjects were shown one map in each of the four un-timed periods. The one choice made by the subject applied to both exits, that is a subject's plan was a pure strategy for the game. Thus if a subject selected "exit" she would take the first exit and choosing "stay" meant she would stay to the end. Hence, one could not take the second exit, a fact that seemed to bother many subjects while reading the directions. Keeping with the driving context, this was explained to the subjects as driving a futuristic car that had to be programmed to exit or stay and was not sophisticated enough to keep track of the exits. This phase of the experiment was thus referred to as the programming phase.

EXPERIMENTAL MAPS

Even with only two exits, there are a variety of map structures that can arise. While the focus of the literature has been on maps in which the paradox arises, other maps provide valuable behavioral information as well. Two classes of maps, which we refer to as optimal stay and optimal exit, have the largest payoff at the end and first exit respectively. Thus on these maps, one can be assured of the highest possible payoff by following a dominant strategy of staying or exiting respectively. Hence, behavior on these maps serves as a measure of subject comprehension in the decision phase. The other classes of maps, including paradox maps, have the highest payoff at the second exit. Formally, a paradox map is one for which the average payoff at the exits is greater than the payoff at the end, but the payoff at the first exit is less than the payoff at the end. A fourth class is similar to the paradox maps in that the average payoff at the exits is greater than at the end, but in this class the payoff at the first exit is greater than the payoff at the end. We refer to this class as the expected exit maps. The fifth class, referred to as expected stay, has an average payoff at the exits that is less than the payoff at the end. A sixth class consists of maps for which the average payoff at the exits equals the payoff at the end, but given the focus of this research such maps were excluded from the decision phase.

Table 1. Experimental Maps by Period

Exit 1	Exit 2	End	Decision	Memory	Planning	Map Type
2	5	1	1,7	1	-	Expected Exit
1	5	4	2,17	-	-	Expected Stay
4	2	5	3,30	14	-	Optimal Stay
3	5	2	4,9	-	-	Expected Exit
4	2	3	5,11	12	-	Optimal Exit
3	5	1	6,27 (13,23)	-	2	Expected Exit
1	3	4	8,15	3	-	Optimal Stay
1	5	2	10,18 (16,25)	4	3	Paradox
2	5	4	13,23 (6,27)	-	4	Expected Stay
1	4	3	12,21 (20,26)	-	-	Expected Stay
4	3	2	14,22	11	-	Optimal Exit
2	5	3	16,25 (10,18)	-	1	Paradox
5	1	3	19,28	15	-	Optimal Exit
2	4	1	20,26 (12,21)	-	-	Expected Exit
2	1	5	24,29	10	-	Optimal Stay
1	4	5	-	2	-	
2	4	3	-	5	3*	
5	2	3	-	6	-	
3	2	4	-	7	-	
1	4	2	-	8	-	
3	1	4	-	9	-	
4	2	1	-	13	-	
2	3	5	-	16	-	

* For the first 11 subjects the map (2,4,3) was accidentally used in place of (1,5,2). To control for possible timing effects, the order of the games of interest was changed for subjects thirty two through fifty four. The periods for these subjects are given in parentheses.

The phases and periods in which subjects observed particular maps are shown in Table 1. In the first decision period, a subject knows the decision applies to the first exit. Since the map changes in the second period, a subject again knows that the decision is for the first exit. Thus, behavior in the first few periods cannot be attributed to absent-mindedness. Therefore, we intentionally did not present a paradox map, two of the expected stay and two of the expected exit maps in the first five periods. Conditional on this restriction and a restriction that a map did not appear within two periods of itself, we randomly selected which maps would be shown in which periods of the decision phase and memory phase. To control for possible timing effects, the ordering of some map pairs was then interchanged for some subjects as shown in Table 1. For the programming phase we hand selected the two paradox maps shown in the decision phase and randomly selected an expected stay and an expected exit map. The periods in which these maps were shown during the programming phase were randomly determined.

III. Experimental Results

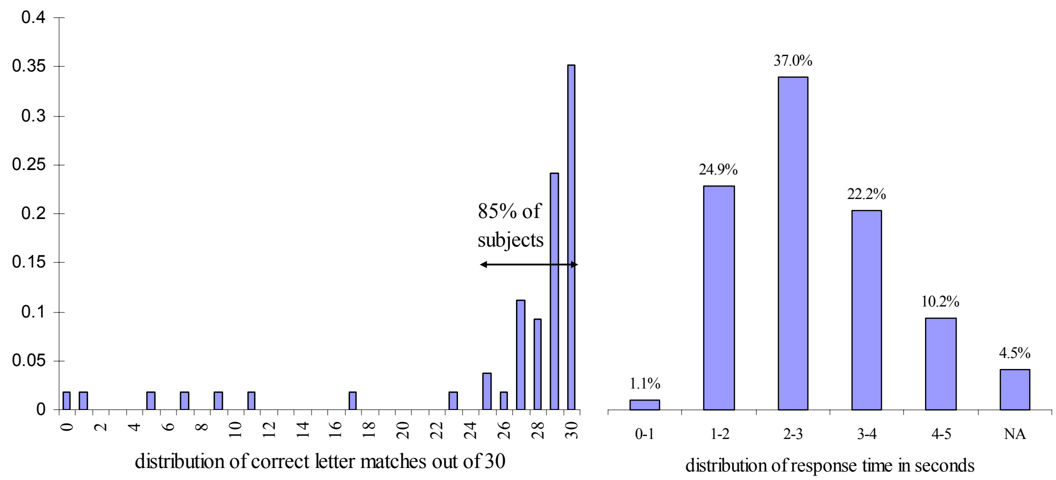
The data consist of responses by 54 subjects. Before evaluating behavior in the decision phase maps of interest, we first check the legitimacy of the results in terms of inducing absent-mindedness.

It is clear that subjects were dividing their attention between the two tasks in the decision phase. The vast majority of subjects correctly matched the letter in at least 25 of 30 periods.[12] The left-hand panel of Figure 2 shows the distribution of correct letter matches. It is interesting to note that in general subjects were very methodical in making the choices within a period; 22% of subjects marked the letter first in at least 90% of the decision periods and 48% made the exit-stay decision first in at least 90% of the decision periods. The right-hand panel shows the distribution of response times to the exit/stay decision, which peaks at 2-3 seconds.[13] The non-response rate to the exit/stay decision was 4.5%. Thirty percent of the instances in which no exit/stay decisions were made occurred in the first three periods of the experiment and 23% of the non-responses came from a single subject.

[12] When asked at the conclusion of the experiment, the person who matched 0 letters correctly indicated that he was focusing only on the maps so as to do better in the memory phase. Incidentally, he answered 8 of 16 correctly in the memory phase. Overall, the correlation with between letter matching and memory was 0.15, which is not significant (Pearson correlation test p-value = 0.2698).

[13] The distribution of response times does not vary substantially with the type of map displayed.

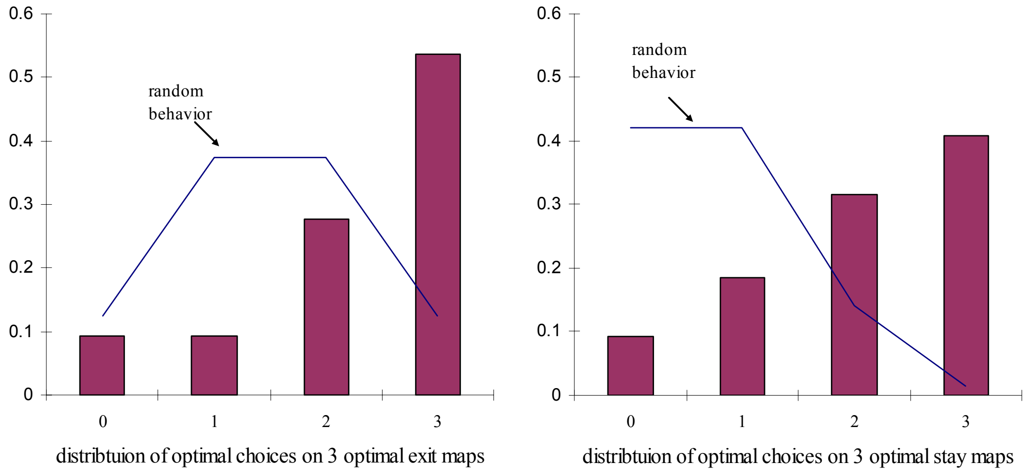
Figure 2. Properties of Responses in the Decision Phase.



As described above, in the optimal stay and optimal exit maps, a subject can be assured of obtaining the maximum possible payoff by following a simple dominant strategy. Hence behavior on these maps serves a control for subject understanding. Over the course of the decision phase three distinct maps of each type were shown to the subjects.[14] Therefore we want to know if the subjects arrived at the correct location more often than would be predicted for random guessing. The left hand panel of Figure 3 shows the distribution of the number of optimal choices on optimal exit maps by subjects. Keep in mind that optimal behavior here only requires a subject to click exit the first time she sees the map, which would happen with probability 0.5. Therefore, the probability that a subject randomly arrived at the optimal location three times is 0.125. Clearly, subjects were doing better than random guessing. This is supported statistically by a Kolmogorov-Smirnov test (K-S statistic = .4074, critical value$_{\alpha=.01}$ = 0.2218).

[14] We included maps from all periods in this part of the discussion as recall should not impact one's decision on optimal stay and optimal exit maps.

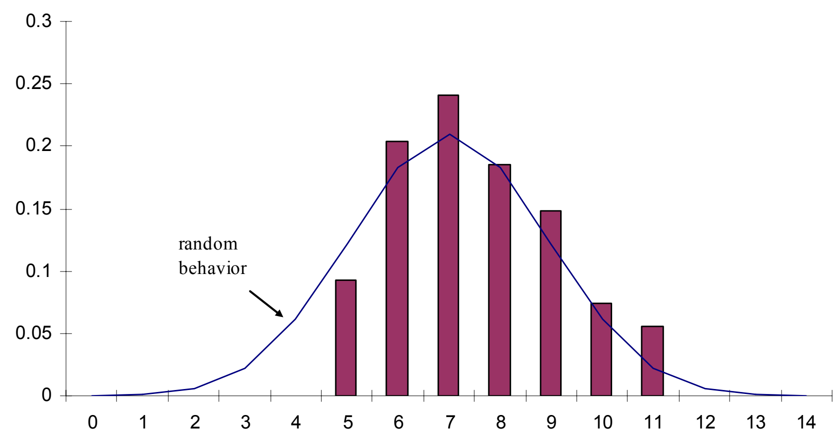
Figure 3. Frequency of Optimal Responses



The right hand panel of Figure 3 shows the distribution of optimal choices on optimal stay maps. In this case arriving at the correct exit requires a subject to stay both times she observes the map, which would occur randomly with probability 0.25. Thus the probability that a subject would randomly arrive at the optimal location 3 times is approximately 0.0156 and we observe over 40% of the subjects behaving optimally on all three maps. Again, it is clear that behavior is better than random guessing (K-S statistic = 0.3918, critical value$_{\alpha=.01}$ = 0.2218). Both this test and the previous one for optimal exit maps are conservative as any subject who did not make a decision at the relevant point was treated as having made an error.

The above results indicate that during the decision phase subjects are making deliberate choices. Of course, this is only half of the problem. The second part is to ensure that subjects cannot recall which maps they have observed while in the decision phase. Our results indicate that we have induced absent-mindedness in our subjects. For this we point to the results of the second phase of the experiment. Figure 4 shows the number of correct memory responses. As previous research indicates that people tend to remember the first and last items in a series, we omit the responses to the maps seen in periods 1 and 30 of the decision phase.[15]

Figure 4. Results of Memory Test.



The subjects' memories were statistically no better than random guessing based upon a Kolmogorov-Smirnov test (K-S statistic = 0.1194, critical value$_{\alpha=.10}$ = 0.1456). The average number of correct responses in the memory test was 7.53, which is slightly higher than the 7 that would be predicted by random guessing.[16] If we break the responses in the memory phase into maps that were used in the decision phase and those that were not, we see a typical pattern of "false memory."[17] People tend to believe they have observed things even when they have not. Overall, subjects reported having seen 57% of the maps when in fact they had only seen 43%. Thus people tend to do slightly better than random guessing on the maps they did observe and slightly worse on maps they did not observe. The average percent of correct identifications of maps that were in the decision phase was 63%, but for new maps the percentage was only 45%. It is also worth emphasizing that by the time the subject took the memory test, she had observed decision phase maps twice, which should improve memory relative to the one time

[15] This is known as a serial position effect; see Glanzer and Cunitz (1966). If the results from the first decision period are included, subjects do perform better than random guessing as nearly all (93%) of the subjects correctly identified having seen map (2,5,1). A sizable number also correctly identified having seen two other maps that used the same numbers, maps (1,5,2) and (2,1,5).
[16] This difference is statistically significant based upon a t-test (t-statistic = 2.42 and p-value = 0.019).
[17] See Loftus (1997) for an accessible discussion of false memories. See also Perez-Mata, Read and Diges (2002) for a discussion about divided attention and false memory.

viewing that is relevant for decision phase choices. Thus our memory test is conservative in that it overestimates recall.

Given that subjects have difficulty recalling what maps they have seen and that they are making reasonable choices in games with optimal strategies, we now turn our attention to behavior in the three interesting classes of maps in which temporal recall is required to reach the maximum payoff; paradox maps, expected exit maps and expected stay maps. Table 2 gives the decisions of subjects on each of these classes of maps.[18]

Table 2. Behavior on Maps of Interest.

Map	**Type**	**Exit, Exit**	**Exit, Stay**	**Stay, Exit**	**Stay, Stay**	**Subjects**
		Exit 1	*Exit 1*	*Exit 2*	*End*	
(1,5,2)	Paradox	51%	14%	14%	22%	51
(2,5,3)	Paradox	59%	18%	12%	12%	51
(3,5,1)	Expected Exit	54%	15%	15%	17%	48
(2,4,1)	Expected Exit	50%	15%	17%	17%	52
(1,4,3)	Expected Stay	22%	14%	20%	43%	49
(2,5,4)	Expected Stay	44%	20%	18%	18%	50

Note numbers may not sum up to a 100 percent due to rounding. The last column is the number of subjects who made decisions both times the map was observed out of a total of 54 subjects.

In our experiments subjects had to make a decision for all maps shown to them. Hence there are four possible decisions (Exit, Exit); (Exit, Stay); (Stay, Exit); and (Stay, Stay). These four possibilities are shown in columns 3-6 of Table 1. Consider the (1,5,2)

[18] As discussed previously, behavior in the first few periods cannot be impacted by absentmindedness. In the first period, the subject knows it is the first period. In the second period it is clear that the decision applies to Exit 1 as the map differs from the period 1 map. For all maps in Table 2, the map was first seen after period 5. Here we only report behavior for subjects who made an exit-stay decision both times the map appeared.

map.[19] On this map 51% exited both times the map was observed and 14% exited the first time the map was observed but stayed the second time it was observed. Hence 65% (= 51% + 14%) of the subjects chose to take Exit 1 while the remaining 35% chose Stay. The 35% who did not take Exit 1 consists of the 14% of subjects who took Exit 2 and the 22% who stayed until the End.

The behavior on map (1,5,2) clearly demonstrates the paradox in which the subjects found themselves. Only 22% of the subjects stayed to the end with the others making an exit decision at some point. Sixty five percent of people took the first exit even though doing so resulted in their receiving the lowest possible payoff. The observed exiting was far greater than predicted by random guessing based on the χ^2 test with p-value < 0.001.[20] Behavior on map (2,5,3) also demonstrates the paradox (p-value < 0.001).

On the expected exit maps, we again observe more exiting than would be predicted by random chance based upon a χ^2 test with p-values < 0.001 for both (3,5,1) and (2,4,1). In fact in both maps only 17% of the subjects stayed to the end. Further, on both maps only about a third of the subjects did not exit immediately. Presumably these subjects were attempting to reach the maximum payoff and opt to stay on these maps. In a sense, these subjects are facing a similar quandary as in the paradox maps in that they want to reach the second exit.

In the expected stay games, like paradox games subjects receive a higher payoff at the end than at the first exit, but the maximum payoff is at Exit 2. The difference is that the end payoff is higher than the average payoff at the exits. Thus there is no inconsistency between the optimal plan and the optimal decision. On map (1,4,3) we find that 43% of the subjects stay at both exits, the modal response. This is statistically grater than what would be observed from random guessing (p-value = 0.0288 in the χ^2 test).The other subjects were presumably attempting to reach Exit 2. This attempt was not successful as approximately two thirds of those who did not stay to the end wound up

[19] Note that this map is the closest to the original Piccione and Rubinstein (1997) absent-minded driver game and has been obtained by adding 1 to all the payoffs.

[20] The statistical analysis of the number of optimal choices and the number or correct memory responses involved order alternatives. However, there is not clear ordering of the alternatives (Exit, Exit), (Exit, Stay), (Stay,Exit), and (Stay,Stay) making the Kolmogorov-Smirnov test inappropriate and thus we rely upon the χ^2 test.

taking Exit 1. Behavior on map (2,5,4) is more perplexing as subjects frequently exited – we find that 44% of the subjects choose to take Exit 1. This gives us a statistically significant result that is in the wrong direction (p-value = 0.0215). This is particularly surprising given that maps (1,4,3) and (2,5,4) differ by a value of one at each location.[21] While false memory, the tendency to believe one has observed things that have not actually been seen, could lead people to believe they are at the second exit, one would expect this to apply to all of the games. Alternatively, if this map initially appeared late in the decision phase subjects might believe they were more likely to be at the second exit, but for 23 of the subjects map (2,5,4) first appeared in period 6.[22]

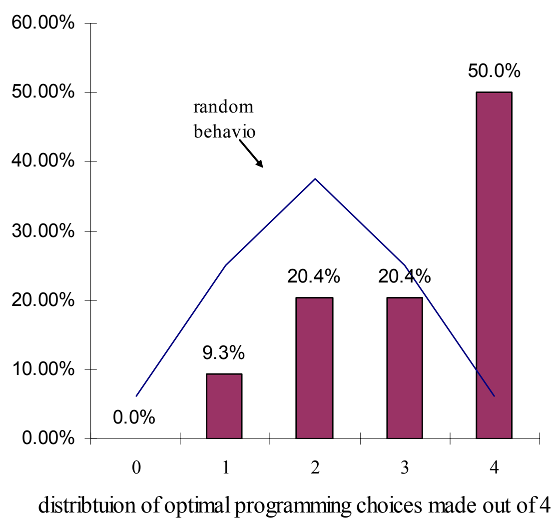
While our experiment was focused on pure strategies, one could also ask, as do Aumann, Hart and Perry (1997a), what is the optimal mixed strategy for map (a,b,c). Let p be the probability of exiting, then a subject wants to maximize $pa+(1-p)pb+(1-p)^2c$. On expected stay maps, the probability of exiting should be 0. But for (3,5,1) and (2,4,1) the optimal probabilities are 0.75 and 0.67 respectively. If subjects are playing this strategy then in aggregate we should see this distribution of choices. One cannot reject this for (2,4,1) but can reject this for (3,5,1) based upon χ^2 tests (p-values = 0.2819 and 0.0260 respectively). For the paradox maps of (1,5,2) and (2,5,3) the optimal probabilities of exiting for maximizing payoffs are 33% and 25%; both of which can be rejected with a χ^2 test (p-values < 0.001). This suggests that the subjects are not playing an optimal mixed strategy in the decision phase.

We now turn our attention to the third phase of the experiment, the programming phase which represents the planning stage. Again, we only allow for pure strategies, so subjects are selecting between exiting and receiving the payoff at Exit 1 and staying and receiving the payoff at the end. Hence, there is a clear optimal choice each period of this phase. Figure 5 shows the frequency with which subjects made the optimal choice in the

[21] Of all the maps studied where recall matters, this is the only pair where such a scaling occurs.
[22] Looking at maps for periods 6-30 in which the maximum payoff was at Exit 2, that is maps for which recall is critical, there is no correlation between period and the percentage of people who exit (Pearson correlation test p-value = 0.9484).

four programming periods.[23] Here too, the subjects did better than random guessing would predict (K-S statistic = 0.4375, critical value$_{\alpha=.01}$ = 0.2218).

Figure 5. Distribution of Optimal Choices in Programming Phase



The paradox arises in that what one would do in the planning stage does not match what one does in the decision stage. For the paradox map (2,5,3) only 31% of subjects went to the same location in the decision phase as they opted for in the programming phase, while 57% planned to stay but ended up at Exit 1. The numbers are similar for the other paradox map (1,5,2) in which only 24% executed their plan and 54% were caught in the paradox. In the expected stay map (2,5,4) only 30% executed their plan but in the expected exit map (3,5,1) we find that 73% of the subjects executed their plans.

IV. Concluding Remarks

[23] Given the simple nature of the untimed and undistracted task, it was not considered necessary to run many periods in the programming phase. Also, during pilot studies many subjects expressed frustration in the directions with the fact that the second exit appeared on the screen but could not be reached. When asked about poor performance in the programming phase, several subjects in the pilot study reported being flustered about what they believed had been a bad performance in the memory test.

In this paper we demonstrate a technique for inducing absent-mindedness in the laboratory that relies on the notion of divided attention. This allows us to provide the first direct test of the absent-minded driver paradox á la Piccione and Rubinstein (1997a). Based on the responses it is clear that subjects in the experiment are spending their time on both the tasks assigned to them, i.e. divided attention is effective in preventing them from focusing on one task. This is also shown to affect their recall.

In the decision phase subjects make decisions for five different types of maps of which two (Optimal Stay and Optimal Exit maps) do not require any recall. These maps serve as a control to test how subjects react to the experimental environment. Results for these maps indicate that subjects deliberately make optimal choices in these two types of games. This result is also reinforced by the programming phase behavior where subjects cannot access Exit 2. A majority of the subjects also make optimal decisions in this phase. Subjects in our experiment undertook a memory test where they had to identify through cued recall which maps had been seen twice in the decision phase. As evidence that we label is absent-mindedness, we find that the subject's memory was no better than random guessing in this phase.

Given that subjects cannot recall what maps they have seen and that they are making good choices in games with optimal strategies, we consider behavior in the three interesting classes of maps in which temporal recall is required to reach the maximum payoff; paradox maps, expected exit maps and expected stay maps. For the two paradox maps we find that a substantial number of subjects get caught in the paradox – only a small number of subjects chose to stay until the end. Behavior in the expected exit maps is similar to behavior in the paradox maps since these games have similar payoff structures. Again only a small fraction of subjects do not chose to take at least one exit. In the expected stay maps behavior is somewhat puzzling since subjects appear to exit more frequently than they should. This could be due false memory where subjects believe that they have already seen a map previously, when they actually have not.

This research demonstrates that it is feasible to examine issues of absent-mindedness using controlled experiments. Replication and further investigation can provide a better understanding of how people make choices under imperfect recall, and thus help in suggesting appropriate theoretical refinements.

REFERENCES

1. Allanport , A, Antonis, B and Reynolds, P (1972) On the Division of Attention, *Journal of Experimental Psychology : General*, vol. 24, 225-35.

2. Anderson, N., T. Iidaka, R. Cabeza, S. Kapur, A. McIntosh, and F. Craik (2000). The Effects of Divided Attention on Encoding and Retrieval-Related Brain Activity: a PET Study of Younger and Older Adults, *Journal of Cognitive Neuroscience*, **12**, 775-792.

3. Aumann, R., S. Hart and M. Perry (1997a). The Absent-Minded Driver, *Games and Economic Behavior*, **20**, 102-116.

4. Aumann, R., S. Hart and M. Perry (1997b). The Forgetful Passenger, *Games and Economic Behavior*, **20**, 117-120.

5. Baddeley, A., V. Lewis, M. Eldridge, and N. Thompson (1984). Attention and Retrieval from Long-Term Memory, *Journal of Experimental Psychology: General*, **13**, 518-540.

6. Battigalli, P. (1997). Dynamic Consistency and Imperfect Recall, *Games and Economic Behavior*, **20**, 31-50.

7. Binmore, K. (1996). A Note on Imperfect Recall, in *Understanding Strategic Interaction – Essays in Honor of Reinhard Selten* (W. Güth *et al*. Ed.) pp. 51-62, Springer-Verlag, New York/Berlin.

8. Board, O., (2003). The Not-So-Absent-Minded Driver, *Research in Economics*, **57**, 189-200.

9. Bonnel, A. and E. Hafter (1998). Divided Attention Between Simultaneous Auditory and Visual Signals, *Perception and Psychophysics*, **60**, 179-190.

10. Bonnel, A., J. Stein, and P. Bertucci (1992). Does Attention Modulate the Perception of Luminance Changes? *Quarterly Journal of Experimental Psychology*, **44**, 601-626.

11. Cooper, D. and J. Van Huyck (2003). Evidence on the Equivalence of the Strategic and Extensive Form Representation of Games, *Journal of Economic Theory*, **110**, 290-308.

12. Cox, J., and C. Deck (2005). On the Nature of Reciprocal Motives, *Economic Inquiry*, **43**, 623-635.

13. Deutsch, J.A and Deutsch, D (1963), Attention, Some Theoretical Considerations, *Psychological Review*, **70**, January. 80-90.

14. Ducan, J. (1980). The Locus of Interference in the Perception of Simultaneous Stimuli, *Psychological Review*, **87**, 272-300.

15. Gilboa, I., (1997). A Comment on the Absent-Minded Driver's Paradox, *Games and Economic Behavior*, **20**, 25-30.

16. Glanzer, M., and A.R. Cunitz, (1966). Two storage mechanisms in free recall. *Journal of Verbal Learning & Verbal Behavior*, *5*, 351-360.

17. Grove, A., and J. Halpern (1997). On the Expected Value of Games with Absentmindedness, *Games and Economic Behavior*, **20**, 51-65.

18. Güth, W., R. Schmittberger and B. Schwarze (1982). An Experimental Analysis of Ultimatum Bargaining, *Journal of Economic Behavior and Organization*, **3**, 367-388.

19. Halpern, J., (1997). On Ambiguities in the Interpretation of Game Trees, *Games and Economic Behavior*, **20**, 66-96.

20. Hirst, W. (1986). Aspects of Divided and Selective Attention, in *Mind and Brain* (J. LeDoux and W. Hirst Ed.) pp. 105-141, Cambridge University Press, New York.

21. Hoffman, E., K. McCabe, K. Shachat, and V. Smith (1992). Preferences, Property Rights, and Anonymity in Bargaining Games, *Games and Economic Behavior*, 7, 346-380.

22. Huck, S., and W. Muller (2002). Absent-Minded Drivers in the Lab: Testing Gilboa's Model, *International Game Theory Review*, **4**, 1-14.

23. Iidaka, T., N. Anderson, S. Kapur, R. Cabeza, and F. Craik (2000). The Effect of Divided Attention on Encoding and Retrieval in Episodic Memory Revealed by Positron Emission Tomography, *Journal of Cognitive Neuroscience*, **12**, 267-280.

24. Kagel, J. and A. Roth. (1995) *The Handbook of Experimental Economics*. Princeton University Press.

25. Kahneman, D. (1973) *Attention and Effmrt*. Englewood Cliffs: NJ, Prentice Hall.

26. Lipman, B., (1997). More Absentmindedness, *Games and Economic Behavior*, **20**, 97-101.

27. Loftus, B., (1997). Creating False Memories, *Scientific American,* **277**, 70-75.

28. Murdock, B. (1965). Effects of a Subsidiary Task on Short Term Memory, *British Journal of Psychology*, **56**, 413-419.

29. Naveh-Benjamin, M., F. Craik, D. Gavrilescu and N. Anderson (2000). Asymmetry Between Encoding and Retrieval Process : Evidence form a Divided Attention Paradigm and a Calibration Analysis, *Memory and Cognition*, **28**, 965-976.

30. Naveh-Benjamin, M., F. Craik, J. Guez and H. Dori (1998). Effects of Divided Attention on Encoding and Retrieval Process in Human Memory: Further Support for an Asymmetry, Journal *of Experimental Psychology: Learning Memory, and Cognition*, **24**, 1091-1104.

31. Naveh-Benjanmin, M., J. Guez, and M. Marom (2003). The Effects of Divided Attention at Encoding on Item and Associative Memory, *Memory and Cognition*, **31**, 1021-1035.

32. Perez-Mata, M.N., J.D. Read and M. Diges (2002). Effects of Divided Attention and Word Concreteness on Correct Recall and False Memory Reports, *Memory*, **10**, 161-177.

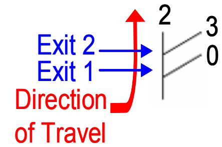
33. Piccione, M. and A. Rubinstein (1997a). On the Interpretation of Decision Problems with Imperfect Recall, *Games and Economic Behavior*, **20**, 3-24.

34. Piccione, M. and A. Rubinstein (1997b). The Absent-Minded Driver's Paradox: Synthesis and Responses, *Games and Economic Behavior*, **20**, 121-130.

35. von Nuemann, J. and O. Morgenstern (1944). *The Theory of Games and Economic Behavior*, Princeton University Press.

APPENDIX: SUBJECT DIRECTIONS

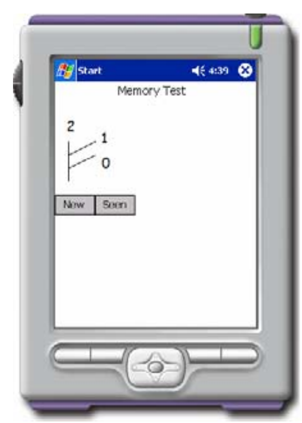
You are participating in an IDEA (Interactive Decision Experiments at Arkansas) research experiment and will be paid a $2.50 participation fee. You will also be paid additional money at the end of the experiment based upon your decisions in the experiment. Therefore, the better you understand the directions before beginning the experiment the more money you will be able to earn. If at any point you have a question, please raise your hand and a monitor will approach you. Otherwise you should not communicate with others (please turn off all cell phones, pagers, etc.).



Imagine yourself driving up the highway as you see on the map alongside. When you approach an exit you have to decide either to stay on the highway or take the exit. If you take the exit then that is the end of your drive. If you decide not to take the first exit, you continue to the second exit. Again you can decide to exit or stay on the highway. The numbers on the map tell you the amount of money in dollars that you would earn based on where you choose to go. In this example, you would earn $0 from taking the first exit. If you do not take the first exit, then when you reach the second exit you would have to decide between earning $3 from taking the second exit and earning $2 from staying on the highway. In this example your maximum earnings would be achieved by staying on the highway at the first exit and then taking the second exit. Some of the decisions you will have to make in today's experiment involve deciding if you want to exit or stay when we show you a map of the highway.

Today's experiment has three phases: 1) a decision phase, 2) a memory test, and 3) a programming phase.

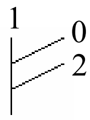
<u>1. The Decision Phase:</u> There will be a series of <u>periods</u> in this phase. Each period will last 5 seconds and you will have two activities to complete in this time.



One activity is an exit or stay decision as described as above, which will appear on the left hand side of your screen. Each period you will make one exit or stay decision for the map shown.

In the decision phase you will see several different maps but you will see each map exactly twice. The first time you see a map your decision applies to Exit 1 and the second time you see the map your decision applies to Exit 2. However, the maps are displayed in a random order so that you will not see the same map in consecutive periods. So rather than making your Exit 1 decision and then immediately making your Exit 2 decision for a map; you will make choices for other maps in between. Hence the map you see in period 1 will not be used in period 2, but it could appear again in period 3, or period 4, or any other period during the decision phase.

You do not know how many periods there are in this phase and it is up to you to remember the maps you have seen so that you know if you are at Exit 1 or at Exit 2 when making a decision. Of course, where you end up depends on both the decisions you make for a particular map. The table below shows the 3 possible cases. Notice that if you choose to exit the first time you see this map, you will still be shown the map a second time even though it does not matter what choice you make the second time.



	Exit 1 Decision (first time to see map)	Exit 2 Decision (second time to see map)	Payoff
Case 1	Exit	Exit or Stay	2
Case 2	Stay	Exit	0
Case 3	Stay	Stay	1

The second activity is a letter matching task. On the top right portion of your screen you will be shown a letter. You will receive $0.10 if you tap the matching response from the four choices before the five second time limit runs out for that period.

You can change the letter you have selected in the letter matching task up until time runs out for the period. However, once you make an exit or stay decision by clicking the appropriate button below the map, you cannot change your choice. If you do not make a map decision during the 5 second period, your payoff will be $0 for that map (it is though you had a wreck on the highway and did not make it to a destination). So even if you are pretty sure that you have seen a map before and chose exit, you will still need to make an exit or stay decision. If you had exited previously on that map, then your decision will not affect your payoff.

At the end of the experiment, one Decision Phase period will be randomly selected and your earnings from the map activity will be based on your map decision for that period and your map decision in the other period in which you saw that same map, since your payoff may depend on what you did at both exits. Please note that while you will be paid based on only one randomly selected map, you will be paid $0.10 for every period in which you correctly match the letter on the right hand side of your screen.

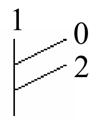
2. The Memory Test: In this phase of the experiment, you will be shown a series of maps. Your task is to identify which ones are new and which ones you saw in the Decision Phase of the experiment. Each time you are correct $0.25 will be added to your total payoff. If you believe that you did see the map in the Decision Phase tap "Seen." If you believe it is the first time you have seen the map, tap "New." There is no time limit in this phase. The number of periods in this phase is fixed, but you do not know how many periods there will be.

3. The Programming Phase: In this phase you will again be shown a series of maps. Like in the Decision Phase, it is as though you are starting at the *bottom* of the map and driving *up* the highway and your payoff will depend on where you go. Your payoff from this phase does not depend on anything you did in the previous phases.

What is different is that in the programming phase you must make a single decision of either always Exit or always Stay for a map. Think of yourself as having a futuristic car that will drive for you, but does not know where you are on the highway. Thus you have to program the car to either always exit or always stay when coming to any and all exits on that map. That is, your one decision to exit or stay will apply to both Exit 1 and Exit 2. Notice that this means you cannot take Exit 2 in the programming phase.

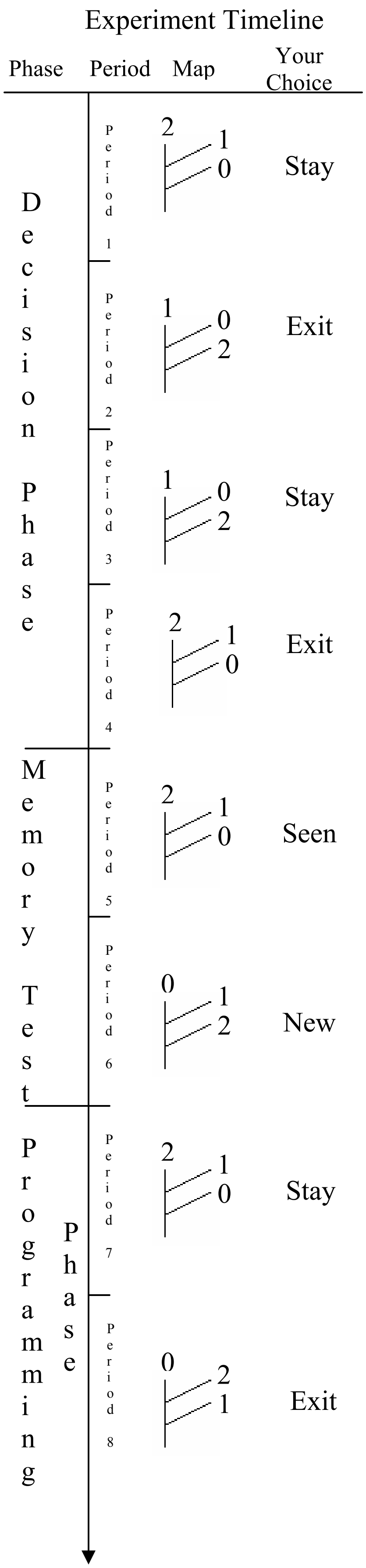
While your choice applies to both exits on a particular map, you can program the car separately for each different map. Since the car drives for you and automatically implements your programmed plan, you will see each map only once during this phase.

Using the same example as before, selecting “Exit” will result in a payoff of $2 as you would exit at the first exit while selecting “Stay” will result in a payoff of $1 because you would stay at both exits and go to the end. This is summarized in the following table.



	Only time you see map	Payoff
Case 1	Exit	2
Case 2	Stay	1

At the end of this experiment, one round will be randomly selected from the Programming Phase. You will be paid based upon your decision for the map in that period. There is no time limit in this phase. The number of periods is fixed, but you do not know how many periods there will be.



Experiment Handout

This handout is to ensure that you understand the tasks you will be performing in this experiment. The maps you see on the left hand side of your screen will not be used in the actual experiment and this sheet will have no impact on your payoff. Suppose that over the course of the experiment, you observed these maps and made these decisions in this order (At the top of the page is period 1 in the Decision Phase followed by period 2 of the Decision Phase. The bottom of the page is the last period in the Programming Phase.) Keep in mind that you see each map exactly twice during the decision phase and do not know how many periods there will be in any phase.

Suppose you made the choices shown, for the decision phase, what would be your payoff

if period 1 is randomly selected?_______

if period 2 is randomly selected?_______

if period 3 is randomly selected?_______

if period 4 is randomly selected?_______

In the memory phase, what would be your payoff

in period 5?_____

in period 6?_____

In the programming phase, what would be your payoff

if period 7 is randomly selected ?_____

if period 8 is randomly selected?_____