2005

Remembering the concentration game : chance or memory?

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REMEMBERING THE CONCENTRATION GAME: CHANCE OR MEMORY?

A Thesis

Presented to

The Faculty of the Department of Psychology

San Jose State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Arts

by

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August 2005

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ABSTRACT

REMEMBERING THE CONCENTRATION GAME: CHANCE OR MEMORY

By Anne Schmidt

This thesis investigated memory performance in the Concentration Game played with different card deck sizes and its comparison to a commonly used memory measurement, the Digit Span Tasks forwards and backwards from the Wechsler Intelligence Scale (Wechsler, 1955). Prior to the study, a mathematical model was developed that could facilitate and generalize the calculation of memory performance in the Concentration Game. A correlational analysis showed no significant relationship between memory performance in the Concentration Game and the Digit Span Tasks. A two factor mixed analysis of variance revealed a mainly linear relationship between the different card deck sizes, in that the more cards people play with the more mistakes they make in trying to finish the game.

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Introduction

The game of Concentration appears to have its origin in a game called "Pick a Pair" published in 1930, although there seems to be an even earlier version found in England under the name "Pelmanism" (Whitehill, 1992). The original Milton and Bradley game "Concentration" came out in 1958 and was based on the famous American television show of the same name. Today, there are many different versions of this game all over the world, and children as well as adults enjoy playing. Concentration is a memory game in which the players must find all matching pairs of a set of cards. To start a game the cards are spread face downward on a table, and the players alternately turn over two cards at a time. Once a pair has been detected it is taken out of the game. The game is finished when all matching pairs have been found.

In Germany the game is called "Memory" which more directly describes the crucial cognitive skill involved. Although it is certainly important to *concentrate* when playing this game, researchers are more interested in studying how effective people's *memory* is in finding the game's matching pairs. Many psychological theories of thinking, problem solving, and intelligence have memory as a key component (e.g., Kahneman & Tversky, 1973; Anderson, 1976; Binet, 1911). For this reason the operating characteristics of many different aspects of memory have become one of the major foci of experimental cognitive psychology.

When playing the game of Concentration, obviously, one has to use different kinds of memory. Not only remembering what cards they have seen but also where they were located. The combination of these two kinds of memory (identity and location) has long been studied, especially in the game of Concentration (e.g., Baker-Ward & Ornstein, 1988; Schumann-Hengsteler, 1992, 1993, 1996a, 1996b).

Throughout her research on visual-spatial memory, Schumann-Hengsteler has examined how locations are remembered (1992), what strategies (1993) and memory codes (1996b) are used to do so, and whether there are any differences in visual-spatial memory between children and adults (1996a). Her research on children's performance in the Concentration Game revealed that there appears to be a different memory subsystem for maintaining spatial information that is distinct from the representation of identity information. According to the procedure used in her study, a picture reconstruction task, the stimuli were presented simultaneously (one picture with multiple items in different locations). Although her data could not provide direct evidence, the author assumed that the children (4-10 years) might use a more holistic representation of the material and were therefore better in remembering the spatial constellation of items rather than their identity (Schumann-Hengsteler, 1992).

In a later study (1993), Schumann-Hengsteler compared the memory performances of four and six year olds and found no significant age differences when examining the recognition of objects and the recall of their locations separately, but when a correct answer required that both the identity and location be correct, six year olds performed better. Schumann-Hengsteler argued that the spatial representation of an object is mostly automatic and therefore developed earlier in children while its combination of visual-spatial is more determined by a player's strategy.

There are different aspects to look at when studying a player's strategy. Although it is assumed that by giving a participant the instructions of the game, the general message of attempting ideal performance is made clear, players still do redundant moves. A move is called redundant if it did not contribute to gaining new information. Redundant moves were also defined as perseveration errors by Eskritt and colleagues (Eskritt & Lee, 2002; Eskritt, Lee, & Donald, 2000), where a card had already been turned over before in the game but the location of its match is still not known.

"Winning" the traditional game of Concentration requires making more pairs than your opponent which calls for efficient use of information. Schumann-Hengsteler (1996a) defined efficiency as "gaining as much information as possible as soon as possible by avoiding redundancy" (p. 80). Considering the memory for identity and location information, an example of redundant moves from the game itself would be the following: A player might remember that they had turned over a particular card in a certain location but they cannot remember what its identity was. This lack of memory might cause them to turn over one and the same card again and again only remembering the location but forgetting what it was. Interestingly, Schuman-Hengsteller (1996a) argues that a non-redundant strategy might not always be the best to use, as a player's memory load increases to an unbearable amount the more new cards they turn over and try to remember. Turning over cards, which the player had actually already seen before but could not yet match (redundant moves) might serve to refresh someone's memory from time to time. This would make it easier to deal with the immense memory load that builds throughout a game. Nevertheless, redundant moves are indicators of memory failure or lack of confidence in memory and they result in less than optimal efficient performance. Any strategy a player might have in using redundant moves purposely to refresh his or her memory could not be differentiated from a memory failure by performance data and has not been studied further in previous literature.

Other strategies researchers have been studying with the Concentration Game are primacy vs. recency strategy (e.g., Gellaty, Jones, & Best, 1988; Schuhmann-Hengsteler, 1993; Arnold & Mills, 2001). Either strategy can be used as soon as a player has the location and identity information available for two matching cards. The question, though, is which of the two cards matching would the player turn over first when attempting to score a match in the following turn? A recency strategy would apply if the player turns that card over first, which he has most recently seen (i.e. in the previous turn). In contrast, a primacy strategy would apply if the player turns over the least recently seen card of the pair first. But, which one is the better strategy to use? Obviously, the primacy strategy is the better one to use because if instead a player first turns over the more recent card and then fails to find its match, they wasted a turn. But when turning over the least recently seen card first (primacy strategy), even if they fail to find it, and turn over another card instead, they can at least try to find the match for this one (Gellaty, Jones, & Best, 1988).

There even appears to be a developmental aspect to the distinction between primacy and recency strategy. In her study with four and six year olds, Schumann-Hengsteler (1993) found that only the six-year-old group exhibited a consistent primacy strategy. It is argued that because children under the age of six are less likely to use a verbal representation of what they have seen, but instead are more prone to a visual representation, they cannot take advantage of cumulatively rehearsing what they have seen for better processing of information and supporting their memory (see also levels of processing by Craik & Lockhart, 1972).

In addition to studying memory performance in the game of Concentration per se, researchers have come to realize the importance of comparing adults and children in this game (Baker-Ward & Ornstein, 1988; Chagnon & McKelvie, 1992; Schumann-Hengsteler, 1996a). Most interesting, though, are the contradictory findings that have emerged from these studies. Ever since Baker-Ward and Ornstein (1988) published their results that children in fact do outperform adults when playing Concentration, various other researchers (e.g., Chagnon & McKelvie, 1992; Schumann-Hengsteler, 1996a) have conducted studies to investigate this claim and, indeed, they failed to find supporting evidence. In comparing their studies, first of all they did not use the same kind of stimulus material. While Schumann-Hengsteler and Chagnon and McKelvie used the original Milton and Bradley Concentration Game, Baker-Ward and Ornstein used pictures of Sesame Street Muppet characters instead. Although they argued that their participants, children as well as adults, were all familiar to the same degree with these Sesame Street characters, the studies still differed in one other important point. Baker-Ward and Ornstein, as well as Chagnon and McKelvie had their participants each play separately, not in a group of two as the original game suggests. Schumann-Hengsteler (1996b) argued that having the participants play in a non-communicative situation deviates from the original setting of the game and does not reflect the actual game character. This discrepancy raises an interesting question. Which version better reflects the memory performance of a player, when they play by themselves or in a group of two or more players?

Indeed, the original version of the game with two or more players better reflects the game's purpose of competition to find the most pairs. But, in terms of building and using one's memory, playing alone should give a better reflection of this performance. Schumann- Hengsteler (1993) argued that when a player turns over the cards by themselves an additional motoric representation for the critical locations is given. Also, when having participants play alone rather than in a competitive game of two, the interplay of memory and chance is totally different. When two or more players are involved in the game, one player's memory performance does not represent his or her actual ability to memorize the game's critical locations and identities of the cards. Instead, what player A might reveal by an unlucky turn (two cards not matching) could give valuable information for a match to be found in the next turn, but it would be player B to find it, as player A does not get another turn unless he has found a match himself. This problem makes one realize that those studies having used competitive games are less able to make strong claims about individual player's effectiveness and strategies. As the studies report players' overall number of turns to solve a game, or the number of perfect matches (two cards are matched once a player knows the location of both cards of a match) this information cannot be analyzed independently from the performance of an opponent.

In contrast, those studies that did have their participants play independently (e.g., Baker-Ward & Ornstein, 1988; Chagnon & McKelvie, 1992) were able to compare the actual memory performance of their participants differing in age. Nevertheless, for all studies using Concentration it is difficult to compare their findings with each other. Primarily, this is due to variations in the kind of performance they are measuring, how they analyze it in their data, the terminology they use, and whether they consider a factor of chance. It does indeed make a difference on players' performance if they were very lucky throughout the game and could therefore reduce their memory load, or not.

For this reason the first purpose of this study was to develop a mathematical model that could facilitate and generalize the calculation of the performance in the Concentration Game for each participant. Taking into account the factor of chance in each game, it can be determined exactly what the maximum number of turns will be for a person to finish the game, assuming perfect memory. Any deviation from this value of maximum number of turns expected will indicate memory failure. The mathematical proof for calculating a person's performance value and a game example with 12 cards will be presented after defining the terminology used in this study.

Terminology of the Concentration Game

The record on players' performance can provide the identity and order of the cards turned over for each turn of the game. One turn is counted for each two cards turned over either matched and removed from the game or turned back over if they did not match. Table 1 provides a taxonomy of the types of turns that can occur during a game. The types of turns in Table 1 categorize all possible occurrences in a game if

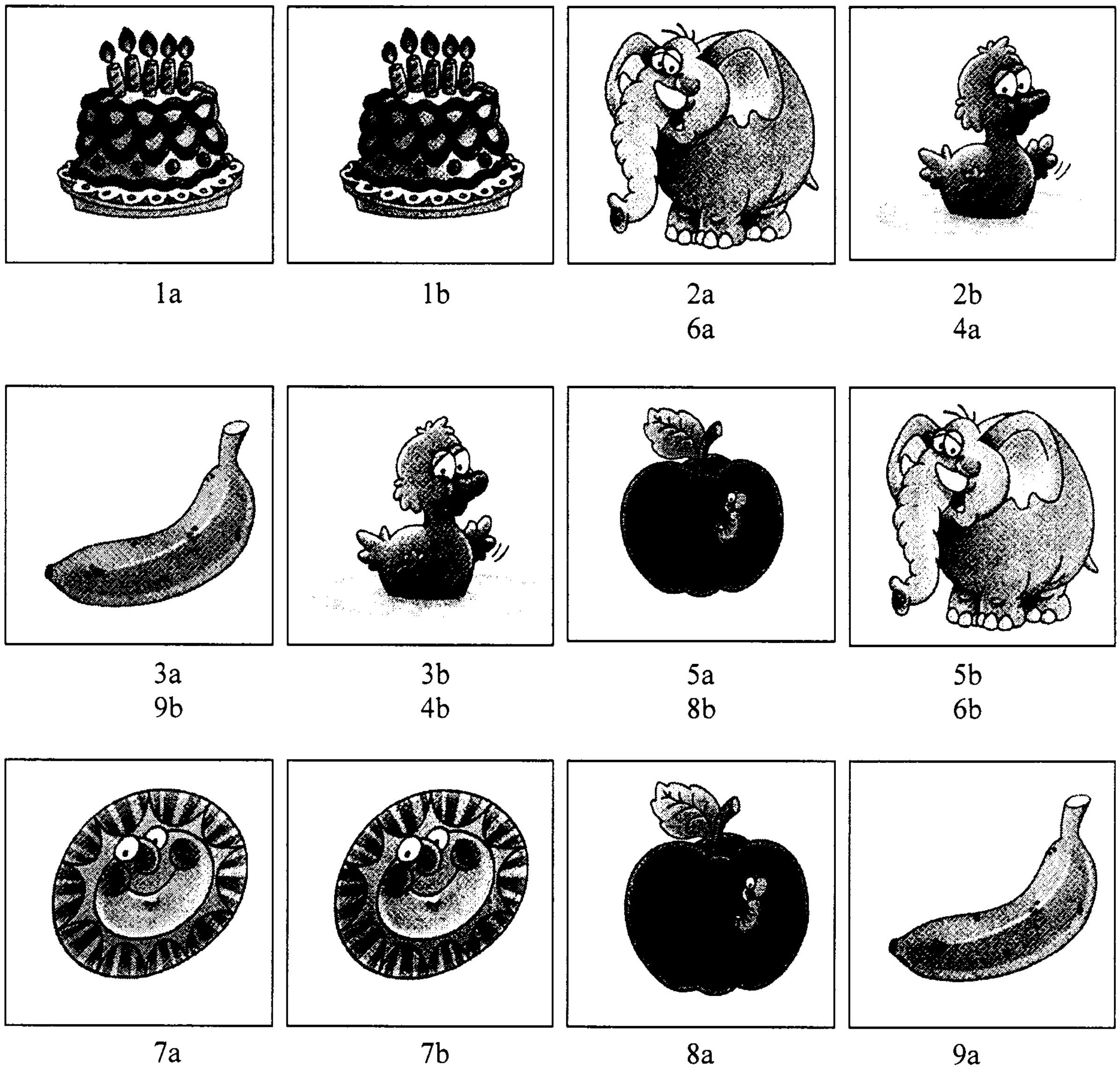
Table 1

The Types of Turns in a Game of Concentration with Perfect Memory and no Error

Type of Turn	Description of the Turn
Lucky match	Two cards turned over are matching and neither has been turned up before.
Unlucky-no-info	Two cards turned over are not matching and neither picture has been seen before. This type of turn adds two cards to a player's memory load without the possibility of triggering a memory match in the next turn.
Unlucky-with-info	Two cards turned over are not matching and the first picture has not been seen, but the second picture has been seen. This type of turn adds two cards to a player's memory load and triggers a memory match in the next turn.
Primary perfect match	Two cards turned over are matching and the first picture has not been seen before but the second picture has been seen before exactly once (in a non-matching pair).
Secondary perfect match	Two cards turned over are matching and each card has been turned over before exactly once, but could not be matched earlier because each appeared in different non-matching pairs.

memory was perfect. With this set of categories it is possible to calculate what the maximum number of turns will be for a person to finish the game, assuming perfect memory and differing degrees of luck. Note that a "perfect match" was first defined by Baker-Ward and Ornstein (1988), as a match that is made as soon as the participant knows the location of both matching cards.

First, let us look at an example of a Concentration Game with 12 cards (Figure 1). In the first turn (lucky match) the player turns over two pictures of a cake without any prior knowledge of either card. The second turn (unlucky-no-info) reveals an elephant and a duck. Unluckily, the player did not find a match. As neither card has been seen before this turn also contains no information to be used to detect a match in the next turn. The third turn (unlucky-with-info) shows a banana and a duck. The duck's matching card had been seen in the previous turn; therefore this third turn contains information which will allow the player to detect a pair in the next turn. In the fourth turn (assuming perfect memory) the duck from the second turn and the duck from the previous turn are turned over and matched. Because this fourth turn involved turning over two cards that had been turned over exactly once each, it is called a secondary perfect match. The fifth turn is again an unlucky-with-info (apple and elephant) and is followed by a secondary perfect match (both elephant cards). The seventh turn is a lucky match since both suns have not been seen before in the game and were matched by chance without the use of any prior knowledge. The eighth turn showing an apple first, forces the player to remember the location of the first card showing an apple. This is a primary perfect match, as the turn started with a card that had not been turned over previously in the



1a/b lucky match
2a/b unlucky-no-info
3a/b unlucky-with-info
4a/b secondary perfect match
5a/b unlucky-with-info
6a/b secondary perfect match
7a/b lucky match
8a/b primary perfect match
9a/b primary perfect match

Figure 1. An example of a sequence of a game with 12 cards and its types of turns.

game. Analogously, turn nine is a primary perfect match for the two cards showing bananas. Notice that we can count the types of turns that occurred in this game, as displayed in Table 2.

The game example revealed two lucky matches, one unlucky-no-info, two unlucky-with-info, two primary perfect matches and two secondary perfect matches. This adds up to nine turns all together. Table 2 also shows another possible outcome when having a game of 12 cards with two lucky matches. Instead of just one unlucky-no-info one could have two unlucky-no-info turns leading to four primary perfect matches and none of the unlucky-with-info or secondary perfect matches. This would have caused the game to finish after eight turns instead. Instead of having 2 lucky matches in a game of 12 cards (6 pairs) one could also have no lucky matches at all or up to 6 all together. Table 3 lists all possible scenarios for a game with 12 cards. In fact, one could create similar situations and display all possible scenarios that can occur in a game of any size of card deck.

The Mathematical Model of the Concentration Game

Studying the pattern of turns more closely reveals a systematic pattern of counting the turns depending on the chance factor in the game. Notice in Table 3 that summing the turns of all types that occur in a game gives the total number of turns to finish the game. Moreover, the various types of turns have predictable interdependencies, assuming perfect memory. Characterizing these interdependencies leads to a simple formula for the number of turns that can occur in any game, given the number of cards in the game and a measure of the chance factor.

Table 2

Possible Outcomes for a Game with 2 Lucky Matches Assuming Perfect Memory

Type of turn	Possible Outcomes	
Lucky match	2	
Unlucky-no-info	2	1
Unlucky-with-info	-	2
Primary perfect match	4	2
Secondary perfect match	-	2
# of turns to finish game	8	9

Table 3

Summary of all Possible Outcomes that Can Occur in a Game with 12 Cards

Type of turn	Possible Outcomes										
Lucky match	-	-	-	1	1	2	2	3	4	5*	6
Unlucky-no-info	3	2	1	2	1	2	1	1	1	-	-
Unlucky-with-info	-	2	4	1	3	-	2	1	-	-	-
Primary perfect match	6	4	2	4	2	4	2	2	2	-	-
Secondary perfect match	-	2	4	1	3	-	2	1	-	-	-
# of turns to finish game	9	10	11	9	10	8	9	8	7	6	6

Note. * 5 (+1). In a game with 12 cards, 5 lucky matches force the last pair to be a lucky match as well.

Definition of Variables

For the mathematical proof let us define the following variables:

N = number of cards in the game,

X = number of lucky matches,

Y = number of unlucky-no-info turns.

Note that however many cards, N, one is playing with there are half as many pairs, N/2, to detect in the game. Since it is possible for an entire game to consist of lucky matches, X can be at most N/2. Since it is possible for the first N/2 cards turned up to be distinct, X can be 0, as in this case, all remaining cards will have pictures that have already been seen. Thus, the range of possible values for X is 0 to N/2, with the exception that X cannot equal N/2 – 1, since N/2 – 1 lucky matches forces the last pair of cards to be a lucky match.

The range of possible values for Y depends on both N and X. The first turn of every game *must* be either a lucky match or an unlucky-no-info. If the game starts with consecutive lucky matches, then eventually, an unlucky mismatch will result or the game will consist entirely of lucky matches. Thus Y = 0 if and only if the game consists entirely of lucky matches, that is, if and only if X = N/2. Suppose X = 0. Then Y must be at least 1. Moreover, since it is possible for the first N/2 cards turned up to be distinct, Y can be as large as ½(N/2), if N/2 is even, or ½(N/2 – 1), if N/2 is odd. Suppose 0 < X < N/2 – 1. Then Y must be at least 1. In this case, there are 2X cards in the game that are removed strictly by chance. Thus, the turns that revolve around the remaining N – 2X cards unfold as if a complete game were played with only N – 2X cards and no lucky matches. In such a scenario, it is possible for the first half of the remaining N – 2X cards turned up to be distinct. Thus, Y can be as large as ½[(N – 2X)/2], if (N – 2X)/2 is even, or ½[(N – 2X)/2 – 1], if (N – 2X)/2 is odd.

Interdependencies Between Turns

First, it is shown that the number of unlucky-with-info equals the number of secondary perfect matches in a game played with perfect memory. Each secondary perfect match involves cards that had been turned over before exactly once, but could not be matched earlier because each appeared in different mismatches. Therefore each secondary perfect match must be preceded by an unlucky-with-info. So the secondary perfect matches are in one-to-one correspondence with the unlucky-with–info.

Second, it is shown why the number of primary perfect matches equals 2Y. A turn resulting in an unlucky-no-info (Y) occurs when the two cards turned up don't match and neither picture has been seen before. One has to wait until each of their matching cards is revealed at some point later in the game. Each card in an unlucky-no-info will be turned up a second time as one half of a primary or secondary perfect match. Logically, for every unlucky-no-info turn there will be the opportunity for two primary perfect matches occurring at some future point in the game. Since each card of a secondary perfect match is in one-to-one correspondence with one card of a lucky mismatch, the second card of each primary perfect match must be in one-to-one correspondence with one card of an unlucky-no-info. Therefore the number of primary perfect matches is always twice the number of unlucky-no-info turns.

Third, it is shown why the number of secondary perfect matches equals N/2 – X – 2Y. There are exactly three types of turns that result in a match: lucky matches, primary perfect matches, and secondary perfect matches. The total number of matches in any game is N/2. Thus, the total number of matches (N/2) minus the number of lucky matches (X) minus the number of primary perfect matches (2Y) must equal the number of secondary perfect matches.

Finally, we note that since the number of unlucky-with-info equals the number of secondary perfect matches and the number of secondary perfect matches is N/2 – X – 2Y, then the number of unlucky-no-info must also be N/2 – X – 2Y.

The Formula Characterizing the Number of Turns

The interdependencies above lead to a simple formula for the number of turns it takes a player to finish a game, assuming perfect memory. The number of turns in a game equals the sum of numbers of each type of turn that occurred. That is, the number of lucky matches (X) plus the number of unlucky-no-info (Y) plus the number of primary perfect matches (2Y) plus the number of secondary perfect matches (N/2 – X - 2Y) plus the number of unlucky-with-info (N/2 – X - 2Y) gives the total number of turns to finish a perfect game. Thus,

$$\text{Total number of turns} = X + Y + 2(N/2 - X - 2Y) + 2Y$$
$$= N - X - Y.$$

In other words, for any card deck size, the number of turns it takes a player to finish a game, assuming perfect memory, is the number of cards they are playing with fewer the number of lucky turns and fewer the number of unlucky-no-info turns.

Comparing the Concentration Game to the Wechsler Digit Span Tasks

This more uniform way of measuring people's memory performance on the Concentration Game raised the question how does memory performance in the game compare to memory performance in a well-established, valid memory measurement. This lead to the second purpose of this study to determine whether people's memory performance in the Concentration Game reflects their performance in a normally used measurement of memory, the Digit Span Subtest of the Wechsler Adult Intelligence Scale (Wechsler, 1955). If players' performance in the Concentration Game represents their ability of general memory performance, the results of the games should be in congruity with those results from the Wechsler Digit Span Tasks. For the purpose of this study it was therefore hypothesized that the memory performance in the Wechsler Digit Span Tasks is a significant predictor of memory performance in the Concentration Game, no matter what card deck size used.

Playing the Concentration Game with Different Card Deck Sizes

In addition to the problem of variation in method and analysis among previous studies, another aspect of research on the Concentration Game appeared to be missing. Although some of the authors have mentioned that the game can be played with different number of cards, none of the previous studies have compared people's performance on different sizes of card sets. It certainly makes a difference not only in the memory load but also with the chance factor whether one is playing with 72 cards (36 pairs) or only 12 cards (6 pairs). Unless a player is very lucky and matches all (or most) of the cards by chance, the memory load increases and the chance factor decreases the more cards one is playing with. Therefore the third purpose of this study was to determine people's performance in a Concentration Game depending on the number of cards they were playing with. It was hypothesized that memory performance in the game of Concentration is a function of card deck size used. The number of cards participants play with is a significant predictor of memory load and memory failure.

Summary of Research Hypotheses

The first research hypothesis assumes that memory performance on the Wechsler Digit Span Tasks is related to the memory performance in the Concentration Game. In particular, it is predicted that there is a significant negative correlation between the performances of both, in that the longer the sequence of numbers remembered on the Digit Span Tasks, the fewer number of turns it will take to finish a game of Concentration. It is also predicted that the ability level on the Wechsler pre-test (low vs. high) will have a significant interaction effect on the Concentration Game performance, which will further support the first hypothesis.

The second research hypothesis proposes that memory performance in the Concentration Game is a function of card deck size used. It is predicted that with increasing number of cards played with, the memory load will increase and cause more memory failures.

Method

Participants

The total sample consisted of 24 volunteers from the area of San Jose, California, who were all acquaintances of the Primary Investigator. The mean age of the participants was $M = 30.29$ ($SD = 10.96$) ranging from 18 to 64. The sample consisted of 54.17% female and 45.83% male participants. Regarding the participants' education status, most of the participants, 45.83%, had a Bachelor degree, followed by 29.17% with a Master degree, 20.83% with a High school degree and 4.17% with a doctoral degree at the point of data collection. Participants all signed a document of informed consent approved by the San Jose State University Institutional Review Board (IRB; see Appendix).

Design

For the purpose of this study a 4 x 2 mixed subjects design was used. Each participant played 4 games of Concentration by him- or herself. The number of cards played with was the first independent variable with four levels (12, 24, 48, 72), the order of those games was randomly assigned to each participant. Performance on a pretest served as a second quasi-independent variable with two levels (determined through median split). The pretest was the original Digit Span Task, forwards and backwards, from the Wechsler Intelligence Scale (Wechsler, 1955). The purpose of this pretest was to assess people's relative memory span for sequences of numbers.

Several measures were collected to map the different aspects of performance, i.e. to differentiate between chance and memory performance in a game. The following measures were counted and recorded in each game: number of cards played with (12, 24, 48, 72), number of overall turns to finish a game, number of lucky matches (match by chance), number of unlucky-no-info (no match, neither of the two cards' matches have been seen before). With this information three different dependent variables could be calculated for the planned analyses of this study, a) the total number of trials to finish a game, b) an absolute memory failure which is a players' deviation from perfect performance (without memory failure), and c) a proportional memory failure which is a ratio of a players absolute memory failure over perfect performance.

Setting and Apparatus

The experiment used the original Memory Game (Milton Bradley Company, © 1996) consisting of 72 colored picture cards of familiar objects, e.g. apple, sun, key. The game consists of two cards of the same picture, i.e. 36 pairs. Because the number of cards in a game served as an independent variable of the study, participants played 4 games, once each with 12, 24, 48, or 72 cards, order was randomly assigned. The game setup was to shuffle and spread the cards picture-side-down on a table. Depending on the number of cards used, there was a nearly square grid with x rows and x + 1 or x + 2 columns formed. (For those games with 12 cards, a grid of 3 x 4 cards was formed, for those games with 24 cards, a grit of 4 x 6 cards was formed, for those games with 48 cards, a grit of 6 x 8 cards was formed, and for those games with 72 cards, a grid of 8 x 9 cards was formed.)

Procedures

Each participant was tested individually. First, the participant was told the purpose of the experiment and asked to read and sign the consent form. Prior to the

Concentration Game itself, participants were asked to perform a pretest. This pretest was the Digit Span Subtest from the Wechsler Adult Intelligence Scale (Wechsler, 1955) in which a sequence of digits was spoken to the participant and he or she was asked to repeat the sequence, forwards on the first part of the test and backwards on the second part of the test. Participants were grouped into either high memory span or low memory span, determined through median split for both the forwards and the backwards part.

Each participant played 4 games of Concentration, 1 game of each card deck size (12, 24, 48, 72). For each game of Concentration the cards were laid out in front of the participant on a table, in a grid determined by the number of cards played with (see Setting and Apparatus). The participant started the game by turning over two cards. If the two cards did not match they were turned face down and the next two cards were turned over. Once a match was found, the cards were taken out of the game. The game was over when all cards were matched. The experimenter watched each game and took notes on the kind of cards turned over on each turn. In order for the experimenter to be able to distinguish the first card of a match with the second card of a match, one half of the pairs had been marked prior to the study with a little red spot, the other half with a little green spot in the right hand top corner on the picture side of the card.

After the experiment the participants were thanked for their collaboration and debriefed.

Results

Digit Span Task and Concentration Game Performances

The means and standard deviations for the Digit Span Tasks are presented in Table 4. For the Digit Span Pretest, participants recalled on average a sequence of 1½ more digits forwards than backwards. A median split for both tasks revealed 12 of the 24 participants to have a high performance on the Digit Span Task forwards, and 12 of the 24 participants being in the group of high performance for the Digit Span Task backwards. The other half of participants were grouped into low performance for each task.

The mean number of turns it took to complete the games and their standard deviations are presented in Table 5. For the game of Concentration it took participants on average the least number of turns to finish a game of 12 cards. Doubling the number of cards to 24 lead to an average of more than twice as many turns to finish the game. Increasing the number of cards to 48 cards lead to a sevenfold average number of turns to finish the game compared to games with 12 cards. Finally, playing with 72 cards required an average of more than 11 times as many turns as playing with 12 cards.

Taking into account the chance factor of each game and calculating the participants' deviation from perfect performance (without any memory failure) revealed the following mean values. Participants had an average failed memory of 1.38 turns (SD = 1.56) for a game with 12 cards, an average failed of memory of 5.29 turns (SD = 4.61) when playing with 24 cards, an average failed memory of 30.46 turns (SD = 17.75) when playing with 48 cards, and an average failed memory of 56.54 turns (SD = 21.12) when

Table 4

Mean Number of Digits and Standard Deviations for the Two Digit Span Tasks

	Digit Span Tasks	
	Forwards	Backwards
N	24	24
M	6.54	5.08
SD	1.44	1.28

Table 5

Mean Number of Turns and Standard Deviations to Complete a Game

	Card Deck Sizes			
	12	24	48	72
N	24	24	24	24
M	10.38	24.33	69.78	116.54
SD	1.56	5.05	18.18	22.11

playing with 72 cards. Because these four values of memory failure are the product of conditions that have different numbers of opportunities to fail, a proportional memory failure for each of the four card deck sizes was calculated dividing the previously mentioned value of memory failure for each deck size by the calculated number of turns to finish a game if one had perfect memory. These ratios then presented a "goodness" of performance for each of the card deck sizes played with. Participants on average received a ratio value of $M = .16$ ($SD = .17$) for playing with 12 cards, $M = .28$ ($SD = .23$) for playing with 24 cards, $M = .77$ ($SD = .44$) for playing with 48 cards and $M = .94$ ($SD = .34$) for playing with 72 cards. Because the ratios were calculated through the difference of actual and perfect performance in the numerator and perfect performance in the denominator, the ratio can be zero only if actual performance equals perfect performance. The greater the deviation of actual and perfect performance the greater the ratio value is. The results of this study show that the larger the deck size was the more the actual performance deviated from perfect performance.

Pearson Correlation Analysis

A correlational analysis was used to test the study's first hypothesis that better performance in a pretest of short term memory would predict better performance in the Concentration Games, no matter what card deck size used. Table 6 reports Pearson correlation for the predictor variables and the criterion variable. For explorative purposes this table also presents correlations with the demographic variables of age, gender and educational status.

First, the results indicate that there is a significant correlation between the two subtests of the Digit Span Tasks (forwards and backwards) $r = .82, p < .01$, showing that the test scores are reliable and that the two tasks index a common memory skill. Those participants who were good in recalling a sequence of numbers forwards were also good at recalling a sequence of numbers backwards. The 8 correlations relevant for the first hypothesis are specially marked (bold) in the correlation table (Table 6).

There was only one of the 8 correlations significant, the correlation between the performance on the Digit Span Task backwards and the memory failure in a game with 24 cards, $r = .44, p < .05$. Counter intuitively, this means that the better participants performed on recalling a sequence of numbers backwards, the more memory failure they showed in a game of 24 cards. These findings did not support the first hypothesis of this study.

The correlational analysis further revealed a significant correlation between gender and the performance on the Digit Span Task backwards $r = -.48, p < .01$, indicating that males were better at recalling a sequence of numbers backwards compared to women. Interestingly, the data also shows that the participants showed more memory failure in a game of 24 cards the younger they were ($r = -.44, p < .05$).

Finally, let us look at the relationship of the 4 different card deck sizes with each other. There was no significant correlation found with the game of 12 cards and any of the other card deck sizes. The games of 24 cards correlated significantly with the games of 48 cards, $r = .56, p < .01$, showing that the better one's performance on a game with 24 cards, the better the performance on a game with 48 cards. The results also show a

Table 6

Pearson Correlations for Demographic Variables, Digit Span Tasks and Card Deck Sizes.

	Age	Gender	Edstatus	DSF	DSB	Deck 12	Deck 24	Deck 48
Age								
Gender	.212							
Edstatus	.261	.176						
DSF	-.096	-.334	-.006					
DSB	-.187	-.482**	-.097	.820**				
Deck 12	-.169	-.208	-.120	**.249**	**.300**			
Deck 24	-.440*	.002	-.090	**.279**	**.438***	.233		
Deck 48	-.259	.041	.141	**.076**	**.051**	-.188	.557**	
Deck 72	-.008	-.047	-.083	**.257**	**.096**	.073	.339	.516**

Note. The 8 correlations relevant to test the study's first hypothesis are bold.

* $p < .05$, ** $p < .01$.

significant relationship between playing a game with 48 cards and playing a game with 72 cards, $r = .52, p < .01$, indicating that the better the memory performance on a game with 48 cards the better the memory performance on a game with 72 cards. The correlation between performance with 24 cards and with 72 cards was positive but not significant ($r = .34, p = .053$).

Analysis of Variance

To test the study's second hypothesis that memory performance in the game of Concentration is a function of card deck size a two factor mixed analysis of variance (ANOVA) was conducted. The within subject factor of card deck size (12, 24, 48, 72) and the between subject factor of performance (high, low) on the digit span were the independent variables. Memory performance in the Concentration task was the dependent variable.

The following data reported are only for the case with the between subject factor of the Digit Span Tasks forwards. The data for backwards performances only differ slightly in their F-values. The degrees of freedom and significance results are exactly the same as for the forwards performance. The analysis of the data for the backwards performances will not be further talked about but only summarized together with the forwards performances in Table 7.

When the total number of trials was used as the dependent variable the overall analysis revealed a significant main effect for deck size, $F\,(3, 20) = 182.86, p < .001$. There was no significant interaction effect found between total number of trials and neither of the Digit Span Tasks, forwards and backwards, both $F < 1$. To find the nature

Table 7

Summary of the Analysis of Variance Testing with Digit Span Task Performance Backwards as the Between Subject Factor

Digit Span Task	Test of Main Factor Deck Size	Test of Inner Subject Contrasts
Backwards $_a$	F (1, 22) = 187.22, $p < .001$	Linear: F (1, 22) = 542.26, $p < .001$ Quadratic: F (1, 22) = 53.69, $p < .001$ Cubic: F (1, 22) = 12.96, $p < .001$
Backwards $_b$	F (1, 22) = 48.77, $p < .001$	Linear: F (1, 22) = 159.76, $p < .001$ Quadratic: F (1, 22) = 26.60, $p < .001$ Cubic: F (1, 22) = 6.02, $p < .05$
Backwards $_c$	F (1, 22) = 34.66, $p < .001$	Linear: F (1, 22) = 105.20, $p < .001$ Quadratic: F (1, 22) < 1 Cubic: F (1, 22) < 12.68, $p < .05$

Note. a: dependent variable of overall number of turns to finish game.

b: dependent variable of absolute memory failure.

c: dependent variable of proportional memory failure.

and source of the significant card deck effect a test of contrasts for the within subject factor revealed a significant linear relationship between the 4 deck sizes, $F\ (1, 22) = 538.10, p < .001$, as well as a significant quadratic relationship, $F\ (1, 22) = 52.16, p < .001$, as well as a significant cubic relationship, $F\ (1, 22) = 12.44, p < .05$. Comparing the three contrast F-values, the data shows that the main component from the relationship between the four deck sizes is linear. The more cards people play with the more number of turns it takes them to finish the game. This supports the second hypothesis of this study.

Investigating the mean values of absolute failed memory the overall analysis revealed a significant main effect of memory failure for the card deck size used, $F\ (3, 20) = 48.51, p < .001$. There was no significant interaction effect found between memory failure and either with the Digit Span Task forwards or backwards. A test of contrasts for the within subject factor revealed a significant linear, $F\ (1, 22) = 159.12, p < .001$, a significant quadratic, $F = (1, 22) = 25.96, p < .001$, and a significant cubic relationship, $F\ (1, 22) = 5.77, p < .001$. Again, the main component of the relationship between the four card deck sizes is linear holding the largest F-value of the three. The more cards people play with the more their memory fails.

Finally, using the calculated proportional memory failure as the dependent variable, the overall analysis revealed a significant main effect of deck size, $F\ (3, 20) = 33.04, p < .001$. Again there was no significant interaction effect found between the calculated ratios and the two Digit Span Tasks, forwards and backwards. Testing the contrasts for the within subject factor revealed a significant linear relationship, $F\ (1,22) =$

99.86, $p < .001$. There was no significant quadratic relationship found (F (1,22) < 1) but there was a significant cubic relationship, F (1,22) = 12.34, $p < .001$. With an F-value of 99.86 for the linear relationship compared to an F-value of 12.34 for the cubic relationship, the association between the four card deck sizes is mainly based on linearity. These findings support the second hypothesis of this study, that the more cards people play with the higher their ratio of failed memory to perfect performance. The non-significant interaction effects between the games of Concentration and the Digit Span Tasks performances only contribute to the findings in the correlation analysis. They do not support the first hypothesis of this study.

Discussion

"Out of sight, out of mind" is one famous aphorism used for so many different occasions; it does certainly apply to the context of the Concentration Game as well. What started as a simple children's game almost 75 years ago, has become so interesting to cognitive psychology. Researchers have studied a variety of aspects in this game. For many years, Schumann-Hengsteler (1993, 1996a, 1996b) has used this game to explore the distinction and combination of identity and spatial memory, or to compare children's memory performance with that of adults. Other researchers focused more on the kind of errors that can occur in a game, as for example redundant moves (e.g., Eskritt & Lee, 2002) or the use of different strategies in the game (Arnold & Mills, 2001; Gellaty, Jones, & Best, 1988). Studies on the Concentration Game have made a huge contribution to the research on memory development and deficiencies in human memory.

Nevertheless, data collection in those studies on memory in the Concentration Game seemed to lack consistency in their attention to chance and differentiating between possible types of turns in the games. It was therefore this study's first goal to develop a mathematical model that could ease the calculation of memory performance in the Concentration Game. This study distinguished different kinds of turns that can occur in a game of Concentration, for that moment assuming perfect memory. These types of turns were called lucky match, unlucky-no-info, unlucky-with-info, primary perfect match, and secondary perfect match. With the help of a mathematical model these kinds of turns made it possible to calculate the maximum number of turns it would take to finish a game considering the given chance factor and assuming perfect memory. Any deviation of a player from this "perfect" number indicated memory failure and could be used for further analyses.

Indeed, this way of calculation made it much more efficient to calculate the players memory failure but it did not distinguish further between what kind of errors occurred. For example, Schumann-Hengsteler (1996a) in her study examined location errors, which occurred every time a player meant to detect a pair but rather grasped the card right next to the right one. Although location errors might only happen by chance, these instances could indicate that a player remembers to have seen a card before and might remember the broader area but is not so sure about its exact location. This way of analyzing errors requires the notation of every card's location in each game. Because every of the 96 games of this study (24 participants each playing 4 games) were randomly spread on the table this notation of all the cards' location could not be realized.

For future studies on the Concentration Game it might be worth considering to give the same pattern layout of cards to every participant and therefore control the cards' relative locations. This would loose its randomized character but could give more valuable information on location errors.

The second purpose of this study was to test the validity of the Concentration Game, if it can really be used as a measurement of memory performance. It was therefore compared to memory performance in the Digit Span Tasks forwards and backwards. For this analysis the player's deviation from perfect performance was correlated to the average performance in recalling different sequences of numbers, forwards as well as backwards. The analysis revealed no such relationship, and therefore did not support this study's first hypothesis. The performance that people showed in the Digit Span Tasks did not resemble their performance in the game of Concentration. What could be the reasons for this result? First of all, let us look at the different content of memory that were measured in these two different memory tests. The Digit Span Task focuses on sequences of numbers of different length, forwards and backwards. Data in this study showing an average length of recalled sequence of $M = 6.54$ ($SD = 1.44$) forwards and $M = 5.08$ ($SD = 1.28$) backwards provides support to Miller (1956), who was right that people can hold about seven plus or minus two items in mind. The card game Concentration instead does not focus on numbers, but rather the identity of pictures they have seen and also where they are located. The memory for pictures does not seem to reflect one's ability to memorize more abstract sequences of random numbers. Many of this study's participants even admitted that they were not good with numbers, but seem to be more confident in their ability to memorize pictures in the following games of Concentration. In addition, the Digit Span Task is of auditory nature while the Concentration Game relies on a visual reception of information.

Besides the different the previous three arguments, another one for these non-related performances in the Digit Span Tasks and the Concentration Games could be the different durations. While the Digit Span Tasks each required about 2 minutes, the Concentration Games were much longer, for a game of 12 cards and especially for those games with 72 cards. When comparing the Game of Concentration with the Digit Span Tasks is one trying to compare the performance of long-term versus short-term memory? If so, the results indicate that one's performance in short term memory does not relate to one's performance in long-term memory. This would then support the old position of Atkinson & Shiffrin's (1968) model of distinction between short-term and long-term memory.

In addition to analyzing the correlations between the Digit Span Tasks and the Concentration Game some other interesting relationships could be found among the data. The correlation analysis did not only use the data of memory performance but also included the demographic variables of age, gender and educational status. The results showed significant negative correlations between the Digit Span Task backwards and gender, indicating that males performed better in recalling a sequence of numbers backwards.

Another interesting finding was that all the correlation of age with each of the deck sizes were negative, but only that with the deck size of 24 turned out to be significant. This indicates that the younger the players the more memory failure they show in a game with 24 cards. It is questionable though if this significant finding might not only been random due to the only small number of participants ($N = 24$). Nevertheless, the revealed relationship between age and memory failure seems worth investigating further. This study's participants were all adults with a mean age of 30, no children and no people older than 65 were involved. In a future study on this topic one would want to increase the number of participants and also have more variability in their age to look further into this relationship of age and memory performance.

In addition to those findings with games of 24 cards, there were also no significant correlations found between the games with 12 cards and neither with the other card deck sizes nor with the pretests or the demographic variables. All games played with 12 cards were close to perfect performance only showing a standard deviation of 1.56 (see Table 5). This ceiling performance showed very little variability and could therefore not correlate significantly with the other performances.

The different card deck sizes were also the focus in the third purpose of this study. It was tested whether memory performance in the Concentration Game is a function of card deck size used. In order to be able to test this study's second hypothesis different kinds of dependent variables representing memory performance were developed to control for the chance factor and the different card deck sizes played with. First, the overall number of trials it took the players to finish the games of Concentration were analyzed and the data showed that the more cards people played with the more number of turns it took them to finish the games. Next, the factor of chance was controlled for and only people's deviation from perfect performance (with perfect memory and no error) was calculated. Again, the data showed increasing numbers the larger the card deck sizes played with. Finally, qualified on the different numbers of opportunities to fail in the four different games of 12, 24, 48, and 72 cards played with, a ratio was calculated which would then allow to truly compare the participant's performances. These ratio values also increased from the smallest card deck of 12 to the largest of 72 cards.

The overall number of turns to complete the games were found to be significantly different from each other. Contrast testing revealed a linear relationship between the four card deck sizes, as well as a significant quadratic and a significant cubic relationship. The same pattern of results was found when the memory failure value was used as the dependent variable. For the analysis with the values of proportional memory failure as the dependent variable, the overall analysis revealed the four card deck sizes to be significantly different to each other, but only the linear and the cubic relationships were significant. Impressing was the contrast of F-values with 99.86 for the linear relationship of the ratio values and 12.34 for their cubic relationship which shows that the main relationship is based on the linear function.

When the ratio values were calculated the increasing number of opportunities to make memory mistakes had been controlled for the more cards were played with. It is therefore very striking that there is still that strong a linear relationship between the four card deck sizes. It means that with increasing memory load, a higher proportion of memory for the cards to be remembered gets lost. There must be something else than just more opportunities to make memory mistakes when playing with more cards. This leads to some interesting thoughts of theoretical appliance to this issue. First, this finding of increased memory failure could be a capacity problem. Once the memory load exceeds the player's fixed memory capacity it would cause errors. For example, a player is able to hold the identity and location of 7 cards (capacity = 7) in his mind. The next new card turned over would already exceed this capacity and one of the following things must happen: it either works like a "push down stack" (e.g. Lupker & Theios, 1975) where the item furthest in the back (here assumedly the first item of the memory load) gets pushed off and gives room for the new one; or another option would be that instead of the item furthest in the back, it rather happens randomly, any item can be the one pushed out of the capacity load to make room for the new one.

Second, it could also be a problem of interference. The more cards are in the game and need to be matched the more intervening trials will occur from the turn one sees a card for the first time until the turn where its match will be turned over. Then one needs to remember where that first card was located at; this information can either have occurred only a couple of turns earlier, or many turns earlier. Obviously, comparing the two extremes of 12 and 72 cards, it will be more likely in a game of 72 cards to have many intervening trials before both cards of a match are found, compared to a game with only 12 cards.

It is not clear whether the finding of increased memory failure are a notion of capacity or an issue of interference. Still, there could be many other reasons which could have caused the low performance of playing with 48 and 72 cards. Some participants seemed to have an additional discouragement facing a game with 72 cards. When they were confronted with that grid of 9 columns and 8 rows of cards some of them thought and said out loud that they will never make it. Also, later in the middle of the 72 cards game, their collected information of location and identity of cards seemed to have collapsed: "Now I am all confused." It seems like it truly makes a differences what the players' own expectations are, their willingness not to give up until they have found all the pairs compared to an almost self fulfilling prophecy of "I will never make it."

Besides the data analysis to test the study's hypotheses, some other important features of this study are worth mentioning. Every one of the 24 participants played 4 games, 1 game each of the four card deck sizes. Originally, it was planed that every participant would play 8 games, two games each with each card deck size. It took every participant about over 1 hour, some of them even close to 2 hours, to participate in the study, instructions, demographic questions, Digit Span Tasks, and the four games included. After this time period, the participants were already "exhausted", and every further requirement of their time and memory would have resulted in no useful data. From the initially planned 8 games the average of the two games for each card deck size were supposed to be calculated and analyzed, but the recourses of this study would not allow this extra in controlling for order effects. Because every player was already randomly assigned to a random order of the four games, the PI decided that it was sufficient enough for controlling randomization and controlling for order effects.

Further, it shall be mentioned at this point that one participant started the study but was not included in the data analysis. The reason was missing concentration and insufficient motivation already in the first of the four games. Participation for this one person was discontinued from both sides, the participant and the PI, and the data was not used for analytical calculations.

Although this study did not include the analysis of the kinds of errors it is still interesting to look at certain similarities in the played games. It has already been said that it cannot clearly be distinguished why a player commits redundant moves. Is it because they forget the cards' identities and fail to detect the right one or do they rather do redundant moves on purpose to refresh their memory. Throughout the played games for this study some of the players seemed to have a certain strategy of order to turn over the cards. For example, starting in the upper left corner of the grid, the players worked themselves through the cards either by row or column. Especially in the large games of 72 cards, it happened in a couple of games that the players eventually went back to that just mentioned upper left corner after they had turned over all the cards once, some matched others not yet. When the participants started over to work themselves through the grid of the left over cards it seemed like they planed to refresh their memory and tried to match them once they thought to have acquired knowledge of the location and identity of both matching cards.

Studying redundant moves in the Concentration Game seems an interesting but also challenging starting point for further research. Analyzing this matter of strategy in games of Concentration would give more confidence in how memory works and when it fails. From a momentarily standing point there seems to be no other good way of testing the use of redundant moves but asking the players either right after a redundant move or at the end of a game. It should be the goal for future research on the Concentration Game to develop models and testing techniques to especially test and control for memory errors.

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From: Pam Stacks,
Interim AVP, Graduate Studies & Research

Date: August 26, 2004

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"Remembering the Concentration game: Chance or Memory."

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to all data that may be collected from the subjects. The approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Pam Stacks, Ph.D. immediately. Injury includes but is not limited to bodily harm, psychological trauma, and release of potentially damaging personal information. This approval for the human subjects portion of your project is in effect for one year, and data collection beyond June 10, 2005 requires an extension request.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services that the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.

cc: Robert Cooper, Ph.D.