The Challenge of Challenge: Avoiding and Embracing Difficulty in a Memory Game

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September 8, 2008

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ABSTRACT

The central prescriptions for using brain games to improve brain health are progressive challenge and brain domain diversification. Exercising a range of cognitive domains is thought to help build a diverse "cognitive reserve." Games that are too easy for a player yield little benefit. Brain games as leisure activities need to be pleasant enough to play to attract and retain players. Designing the appropriate level of challenge is further complicated by vast differences in cognitive abilities between players of different ages and among individual players even if they are the same age.

Theories about mindset and motivation suggest that some individuals welcome hard challenges and others avoid challenge. Challenge avoidance has not been studied in the context of game play. Players who make choices that minimize the challenge in a brain game may unintentionally reduce or eliminate the hoped for benefits.

This manuscript provides preliminary results of an ongoing study. Game play data is analyzed of players who had played between 95 and 1149 rounds of Keep It In Mind (a memory game). About one fourth devoted most of their rounds of play they could consistently succeed at, resulting in average accuracy scores of 91% or higher. These challenge avoiders only modestly challenging their memory. Another 42% tried to remember slightly more items, succeeding 85% to 90% of the time. One third were more extreme challenge seekers, so much so that they succeeded only an average of 80% to 83% of the time. The middle group appeared to reap more cognitive benefit from playing than did the more extreme approaches to challenge, although the differences approach but do not achieve statistical significance ($t=-1.54$, $df=2,23$, $p=.138$).

INTRODUCTION

Cognitive exercises are the mental parallel to physical therapy. A neurologist may recommend that a patient follow a specific cognitive exercise routine, specifying frequency and duration of exercise as well as exactly what exercises to complete. Low patient compliance with physical and cognitive therapy exercise prescriptions is a common problem (Sluijs, Kok, and van der Zee, 1993). Recently, brain games, such as Nintendo's Brain Age, have become popular. Brain games, with their dual promise of fun and cognitive exercise, try to entice players to play in ways that benefit their brain. Brain games more closely parallel a gym or health center than physical therapy, because how often members show up and what activities they engage in is left up to the individual rather than being prescribed. Gym members show up with a goal of health benefits, but some pursue a more vigorous workout than others. A critical factor in the health benefits of going to a gym or playing brain games is whether participants challenge themselves sufficiently during voluntary activity to gain the desired physical or cognitive benefits.

In our study, older adults volunteered to participate knowing that the study involved some kind of intervention to exercise cognitive functions, but not knowing it involved games. All were cognitively healthy mature adults who were playing specifically with the goal of maintaining or improving brain function. We examined the actual play behavior of this sample as they used a short-term memory game over a six week period. Players were classified based on their affinity for or aversion to challenge. Implications related to cognitive benefits, brain game design and game design in general will be discussed.

Age-related cognitive decline had long been considered inevitable and irreversible, including declines in processing speed, sensory integration and memory function. New research has reversed conventional wisdom, uncovering surprising potential for brains of all ages to change (for example, Mahncke et al., 2006). *Brain plasticity* refers to lifelong capacity for physical and functional brain change. Research now shows that learning (and living) constantly changes the brain. Negative plasticity changes degrade brain function. Positive plasticity changes can to some degree restore the declines seen in cognition with normal aging or neurological impairment.

Research on brain plasticity implies that benefits from playing cognitive games derive from exercising diverse cognitive domains (Fernandez, 2008) and from taking on challenges hard enough to stretch the brain (Fernandez, 2007). In other words, the way a player plays a brain game is expected to influence whether and how much playing that game exercises and stretches his or her brain.

Research documents a range of motivations different players have for playing. Games and emotion expert Nicole Lazzaro conducted research tracking 30 emotions individuals experience during game play. She found that four emotions play the biggest role in player experiences: Fiero (the fun of mastering a hard challenge), Curiosity, Relaxation, and Amusement (Lazzaro, 2007). A survey of nearly 2,200 PopCap games players found that 76% of their players were female with an average age of 48 (POPCAP Games, 2006). Two thirds of female players aged 50+ played daily. Among the female players surveyed 90% say they play for stress relief and 73% play for cognitive exercise. Playing to relieve stress and playing to exercise one's brain are potentially contradictory motivations.

Players who are strongly motivated by the "fiero" emotion that arises from the thrill of overcoming hard challenges are ideal candidates to benefit from brain games. Players who play for relaxation and stress relief may avoid rather than seek hard challenges. If so, they will probably receive less cognitive benefit from playing those same brain games, even if they play for the same amount of time as their achievement-oriented peers.

Prescription for Brain Health: Diversification and Challenge

The central prescriptions for using brain games to improve brain health are progressive challenge and brain domain diversification. Exercising a range of cognitive domains is thought to help build a diverse "cognitive reserve" the brain can draw upon in the face of injury, illness and age-related changes (Scarmeas and Stern, 2003). In contrast, exercising only well developed, preferred cognitive domains is thought to add little new benefit. For example, an avid lifetime crossword puzzle player likely does not receive very much added benefit from playing his or her 2000th puzzle, but trying to solve an unfamiliar logic puzzle that requires executive planning and visuo-spatial cognition would exercise unused parts of the crossword specialists' brain (Fernandez, 2007).

Games that are too easy for a player yield little benefit. New neural connections are believed to be more likely to arise when a player encounters just the right level of challenge, a game that is hard enough to evoke what Gee (2007) describes as "pleasant frustration" but not so hard as to be impossible. Through his research on happiness, Csíkszentmihályi (1990) defined the psychological state of "flow," an ideal, euphoric state evoked when challenge and personal ability are in optimal balance. If the challenge is too little, boredom results. If the challenge is too great, frustration occurs.

Flow is often a game design goal. Game designers try to introduce more challenge as the player progresses. However, the central goal of a game for entertainment is pleasure, while the central goal of a brain game is effective cognitive exercise. A brain game that is fun but too easy fails to deliver on its promise. At the same time, cognitively healthy players who elect to allocate leisure time to playing brain games do so expecting fun and cognitive benefits. Brain games as leisure activities need to be pleasant enough to play to attract and retain players. Designing the appropriate level of challenge is further complicated by vast differences in cognitive abilities between players of different ages and among individual players even if they are the same age.

Theories about mindset and motivation suggest that some individuals welcome hard challenges and others avoid challenge. Challenge avoidance has not been studied in the context of game play. Players who have a predilection toward avoiding challenge are likely to make choices that minimize the challenge in a brain game, reducing or eliminating the expected benefits.

Mindset and Motivation

Dweck (2006) has studied how people approach or avoid challenge in a school context. She found that about 42% of the population has what she calls a Growth, or Mastery mindset. Such individuals believe that intelligence is malleable, that they are capable of improving. Another 42% of the population holds a Fixed or helpless mindset. They believe that intelligence is fixed and cannot improve. They avoid situations that they cannot easily do well at. Failure undermines their confidence and they become depressed and ineffective. Having a Fixed mindset can undo a natural love of learning. In contrast, effort and learning make mastery-motivated students feel good about their intelligence; easy tasks waste their time rather than raising their self-esteem. (The remaining 16% cannot be classified as either Fixed or Mastery.)

According to Dweck (2006), mindsets can "change the meaning of effort" (p. 39). She describes American popular culture as reinforcing the idea that people have to either be smart or hardworking, but not both, to succeed. She cites as an example the children's story about a race between a tortoise and a hare. The slow tortoise plods along and wins because the much faster hare gets distracted before reaching the finish line. She concludes not that we grow up wanting to be plodding tortoises, but that we want to be smarter hares. Our culture expects and reveres effortless perfection. According to the Fixed mindset, effort is only necessary for people with deficiencies. Extending that logic, trying, which implies deficiency, and then failing even though you tried (deficient and a failure) is what people with a Fixed mindset fear the most.

Research on students who are extrinsically motivated to do well in school (those motivated by earning good grades rather by love of learning) further illuminate Dweck's Fixed mindset. Elliot and Church (1997) considered two quite different reasons individuals may have for pursuing performance goals such as grades. Performance-approach goals are linked to displaying competence and earning a favorable judgment. Performance-avoidance goals focus on trying to avoid failure. Elliot and Church found positive outcomes for performance-approach goals including positive emotions and absorption in the given task. Performance-avoidance prompted efforts to escape potential consequences of failure and was associated with anxiety. Performance-avoidance interfered with mental focus, blocking the individual's ability to concentrate and become absorbed in an activity. The performance-approach goals approach encouraged mental focus.

Fixed mindset, performance-avoidance individuals are likely to experience anxiety playing competitive games, and if there is a face-saving way to select easy challenges, they are likely to do so. These types of players are also the least likely to benefit from playing brain games, unless the game itself can be designed to coax them into a Mastery mindset.

Keep It In Mind

"Keep It In Mind" (KIIM) is a brain game, created by the Michigan State University Games for Entertainment and Learning Lab, specifically designed to help players concerned about maintaining and improving cognitive functions. It exercises working memory.

On a scale from exercise to game, Keep It In Mind is closer to an exercise. Game elements such as pleasant visual and auditory feedback, keeping score, and progressive challenge modestly enhance the fun beyond a typical memory exercise. Typically verbal memory exercises tend to be based on remembering groups of words of little interest to the individual. For example, a mental aerobics exercise in The Memory Prescription, a book offering a 14-day prescription of cognitive and physical exercises and diet for brain health, challenges an individual to remember five words: "flag, dune, card, heart, fence" (Small, p.41). Another way fun is enhanced in Keep It In Mind is by letting players work on remembering things they are interested in, such as dog breeds, spices, or travel destinations.

The basic game mechanic of Keep It In Mind is remembering a sequence of progressively longer lists of items. Players are first shown two items and instructed to "remember these items, in the order shown" (Figure 1). When the player is ready, they click "*I'm Ready*"**.** The screen then changes to a randomly ordered grid of the objects they had been asked to remember intermixed with other objects not on the list (Figure 2). Players click on the items they recall, in the order those items were presented. Each player's choice is either right or wrong.

Much like an adjustable weight lifting exercise machine, Keep It In Mind allows players to configure a customized workout. Players are in complete control of the amount of challenge they encounter. Before a play sequence begins, players set two preferences. CHOICE 1: Players choose the *cognitive domain* they want to exercise (numbers, letters, words, patterns, objects). CHOICE 2: Players choose a *difficulty setting* (easy, medium, or hard). Easy challenges present items to remember that are quite different from each other, and the player picks out the items shown from a smaller grid of choices. Medium challenges include items more similar to each other and a larger grid of choices. Hard challenges add a twist to the medium challenge such as remembering items in the reverse of the order shown OR in alphabetical OR reverse alphabetical order.

Figure 1: "Remember these words, in the order shown below…"

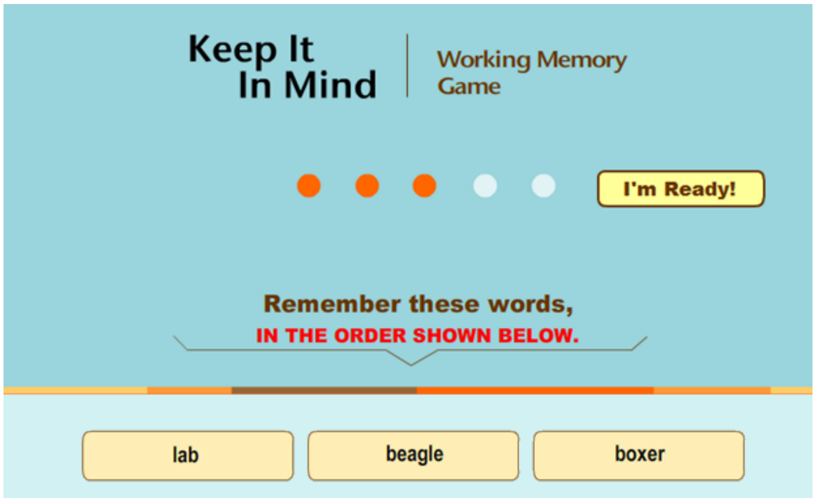


Figure 2: "Now find the words you remember, in the order they were shown."

Motivation and Self Challenge in Keep It In Mind

For every sequence of Keep It In Mind, players make an overt choice to configure their difficulty setting. Within any difficulty setting, players also have control over their *round progression*. When the player accurately recalls 100% of the items, they have a choice of advancing to the next level (remembering one additional item) or replaying the same number of items. If they fail to remember 100%, the player has a choice of replaying the same number of items or going back to one fewer item (but not less than two items). For example, after successfully remembering a 2 item round, the player can choose to "go back to 2 items" OR "continue to 3 items". Players who keep replaying the prior level avoid facing the harder challenge of trying to remember more items. Players are free to end the sequence at any point and start over or they can keep trying to remember additional items, up to the maximum of seven.
An additional form of challenge in the game is *speed*. Each round is timed, and players receive feedback about their speed (from AMAZINGLY FAST to SLOW). The speed meter can easily be ignored, but playing faster is available as a means to improve their score for players who are motivated by scores, by challenge, or both.

METHODS

Healthy, community-dwelling seniors aged 60-80 in the greater Lansing area were recruited from an already existing database of older adults (a research psychologist at MSU who studies the effects of aging on cognition maintains a database of about 100 healthy seniors) and, through advertisements in local newspapers and at local senior living communities.

Recruiting solicitations invited volunteers to participate in an experimental program designed to assess whether regular cognitive exercise can help to improve thinking and memory skills in older adults. They were told the research was based on the principle of brain plasticity- that brain connections can become weaker with disuse and aging, but can be strengthened again through the right kinds of mental exercise.

Initial screening and all cognitive testing took place on campus. Subsequent study participation could occur from any internet-connected location in the world. However, it is likely that most participants logged in from their homes.

To be included in the study, participants had to meet the following criteria:

- have access to a reliable, functioning computer with internet access
- be between 60 and 80 years old
- be able to see and hear well
- have no excessive concern regarding declining cognitive function (especially progressive forgetfulness or memory loss)
- have normal baseline cognitive functioning and no severe medical or psychiatric illness (as measured by the SLUMS Mental Status test (Tariq et al, 2006).

Participants were asked to play any combination of four games, including "Keep It In Mind," for at least half an hour per day, five days per week, for six weeks. They received incentive payments of up to $60; $5 for each week that they logged in to the program at least 5 times for at least 30 minutes, and an additional $30 at the end of the study if total logged time exceeded 1600 minutes. At the time of this analysis (with some additional data collection underway)), 35 subjects had participated.

This article examines how these players interacted with one particular game, "Keep It In Mind," a short term memory game. The KIIM game gave players the ability to set two parameters: difficulty (easy, medium, or hard) and brain domain (numbers, letters, words, patterns, or objects). Players also decided how many items to remember for every round, either increasing by one item, staying at the same level, or decreasing by one item. The prescription for a good mental workout would be to gradually work up to higher difficulty levels, to try to remember as many items as possible, and to do so in all five brain domains at increasingly fast speeds.

RESULTS

Slightly more than three fourths of the study participants (77%) played Keep It In Mind, for at least 95 rounds. The analysis focuses on these frequent players.

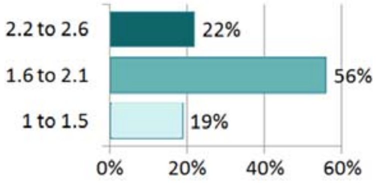
Based on how old they would be in 2008, KIIM players' ages ranged from 60 to 81, with an average of 66.9 (n=21, 6 missing data). Eleven were female, 12 male, and 4 missing data. The 27 frequent players played for an average of 466 rounds, ranging from a low of 95 to a high of 1149.

Difficulty Setting

Most players spent their time playing moderate difficulty levels. The average difficulty played on a scale from 1= easy to 3 = hard was 1.9 with a range from 1 (three players ALWAYS played "easy") to 2.6. Nearly one fifth of players played mostly at easy to somewhat easy levels. (See Figure 1. Figures in the results section use dark turquoise to suggest challenge-seeking behavior, light turquoise to suggest challenge-avoiding behavior and medium turquoise to suggest moderate challenge-seeking.) Another fifth played at moderate to hard average difficulty. The majority (56%) averaged closer to moderate than easy.

Figure 1

Average Difficulty Setting (1= easy, 2=medium, 3=hard)



The average difficulty level obscured distribution of play across easy, medium, and hard rounds. Looking in more detail at the percent of hard rounds shows that one third of players never even tried a "hard" round. The most extreme challenge-seeking player tried a single easy round and moved on to bigger challenges. That particular player chose the HARD level 67% of the time. The two closest challenge-seeking competitors choose hard rounds 49% of the time which is far more than most players but far less than the leading challenge-seeker. Challenge-avoiders are the counterparts to challenge-seekers. Three challenge-avoiding players played 90% or more of their rounds at the easy level, including the person who played all but one of 244 rounds at the easy setting, forgoing moderate and hard setting while maintaining an average accuracy of 92%.

Figure 2

Accuracy by Difficulty Setting

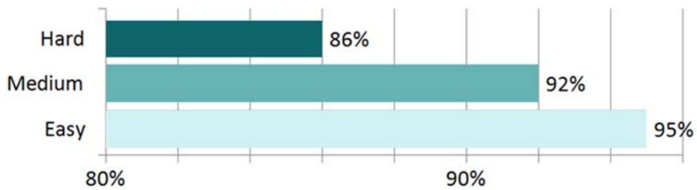


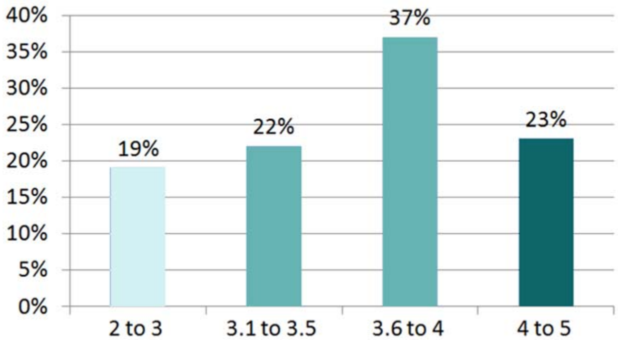
Figure 2 shows that average accuracy was highest across all players at the easy difficulty setting (95%). Average accuracy drops to 92% for the medium setting and 86% for the hard setting.

Inferring player mindset based on play data is confounded by player ability. For example, three players tried the hard difficulty setting for only 10 to 13 rounds. One participant that displayed characteristics of a challenge avoider had the best average accuracy of any player at the hard setting (96%), but mysteriously dropped back to easier difficulty settings after just 10 rounds. That player seems to be playing well beneath his or her ability. Another who dabbled with the hard setting but abandoned it probably made a good choice for her or his own cognitive benefits. This player had very poor accuracy (66% and 71%) at the hard setting, and performed much better, though far from perfect, (83% and 90%) at a moderate difficulty. For this player the hard difficulty setting was probably overly frustrating whereas the moderate difficulty seemed to provide a more reasonable challenge.

Number of Items Attempted

The difficulty setting is the most overt indicator of challenge but it is not the most important factor. Keep It In Mind was originally designed for all players to progress from 2 up to 7 items every time they played. When we added the ability to repeat the same level after a success, and to go back to an easier level after a failure, we assumed players would still generally “level up” to achieve the maximum of 7 items. Instead, players challenged themselves to remember far fewer items than we had intended. Figure 3 shows the average number of items played.

Figure 3
Average Number of Items Played

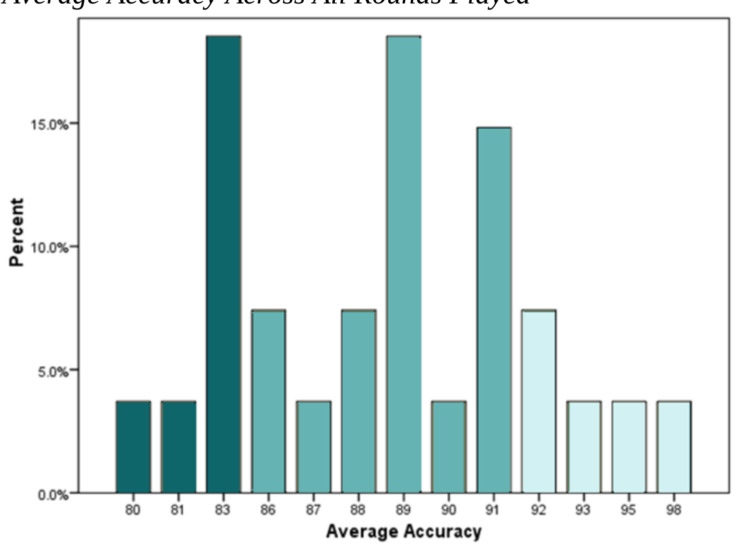


More than half of the players (56%) never tried to remember 7 items. Thirty percent never tried to remember 6 items. (Note that players had to move progressively, so not attempting 6 precludes ever getting to 7.) All players attempted 4 items at least once. (One attempted four items ONLY once, achieved 100% accuracy that one time, and returned to playing only 2 or 3 item challenges for the rest of the 6 week experiment.) All except that one player attempted 5 items at least twice. The two who tried five items only twice scored poorly and gave up. One had an average 5-item accuracy of 50% and the other 80%.

Accuracy

Across all rounds, the average percent of items accurately recalled was 88.1%. There was considerable variation across players. The lowest average accuracy was 80%, and the highest was 98%. (See Figure 4.)

Figure 4
Average Accuracy Across All Rounds Played



Accuracy in Keep It In Mind is measured by the percent of items successfully remembered. If a player attempts to recall 4 items but successfully remembers only 3, his or her performance on that round is 75%. A player must successfully remember items at one level before they can move up to remembering the next item. Each successful round thus results in 100% accuracy for that round.

Challenge

Keep It In Mind players could control the level of challenge they faced, both by choosing the difficulty level, and more importantly, by choosing how many items to try to remember. Whether playing at easy, moderate, or power difficulty, it is much easier to remember 3 items than it is to remember 7.

Memory ability is different in different people. It is likely that some 60 to 80 year olds would be seriously challenged by playing at the easiest settings, and others may not be challenged at all by playing at the most difficult settings. To incorporate individual ability differences, we defined challenge based on the average accuracy across rounds of play. Players who consistently succeed at the challenge they choose are playing within their ability rather than challenging their ability. Those who perform less perfectly are selecting challenges that stretch their ability. By using the measure of average accuracy as a reverse indicator of self selected (or perhaps, self-inflicted) challenge, we can look past differences in ability.

None of the players in this sample achieved high accuracy because they had reached the limit of how challenging the game could be. Even the most challenge-seeking players mostly did not play the game to the limits of the challenge it could have offered.

Figure 5 shows a portrait of players who played at high, moderate, and low levels of self challenge. This variable was constructed based on players' average accuracy. (See column 5 of the figure.) High self-challenge players had an average accuracy of 82% (ranging from 80% to 83%). Moderate self-challenge players had an average accuracy of 88% (ranging from 85% to 90% accuracy). And low self-challenge players had an average accuracy of 93% (ranging from 91% to 98%).

Figure 5

Mental Status, Rounds Played, Overall Accuracy, Items Attempted, Item Speed, and Memory by "Self-inflicted Challenge"

Self-inflicted Challenge	n	Mental Status (SLUMS)*	Rounds Played	Overall Accuracy X (SD)	Avg # of Items Attempted	Item Speed (seconds)	Pre-Post Memory Improvement X (SD)**
High	7	27.6 (1.0)	380 (254)	82% (1%)	3.8 (0.4)	5.6 (1.1)	+06 (.26)
Moderate	11	26.9 (2.5)	410 (293)	88% (1%)	3.7 (0.4)	6.4 (1.7)	+.19 (.26)
Low	9	28.1 (2.3)	601 (348)	93% (2%)	3.2 (0.8)	5.1 (1.0)	+.02 (.24)
		F=0.79, df=2,24	F=1.35, df 2,24	F=69.69, df 2,24	F=2.88, df 2,24	F=2.23, df 2,24	F=1.16, df=2,22 (2 subjects did not take post memory test)
	27	p=.464	P=.277	p=.000	p=.076	p=.119	P=..331

**SLUMS is a 30 item mental status instrument developed by Saint Louis University. Scores range from a low of 0 to a high of 30 (Tariq et al, 2006).*

***Based on the cogState working memory test administered before and after participation in the study. The Pre-Post Memory Improvement column shows the average difference between the pre- and post-working memory score. Zero would be no change. Negative numbers indicate a worsening and positive numbers an improvement in working memory.*

There were no significant differences among the three self challenge groups' initial mental status as measured by the SLUMS 30 item mental status task. Low challenge players averaged 601 rounds of play and high challenge players 380, but these differences were not statistically significant. Low self challenge players appear to have achieved their higher accuracy scores by limiting the number of items they attempted to solve. Low self challenger solved an average of 3.2 items, compared to 3.7 items for moderate self challengers and 3.8 for high self challengers (p=.076).

There was a tendency for moderate self-challengers to play slower. The average per item speed for moderate self challengers was 6.4 seconds compared to 5.1 seconds for low self challengers and 5.6 for high self challengers. This difference approached but did not achieve significance (p=.119).

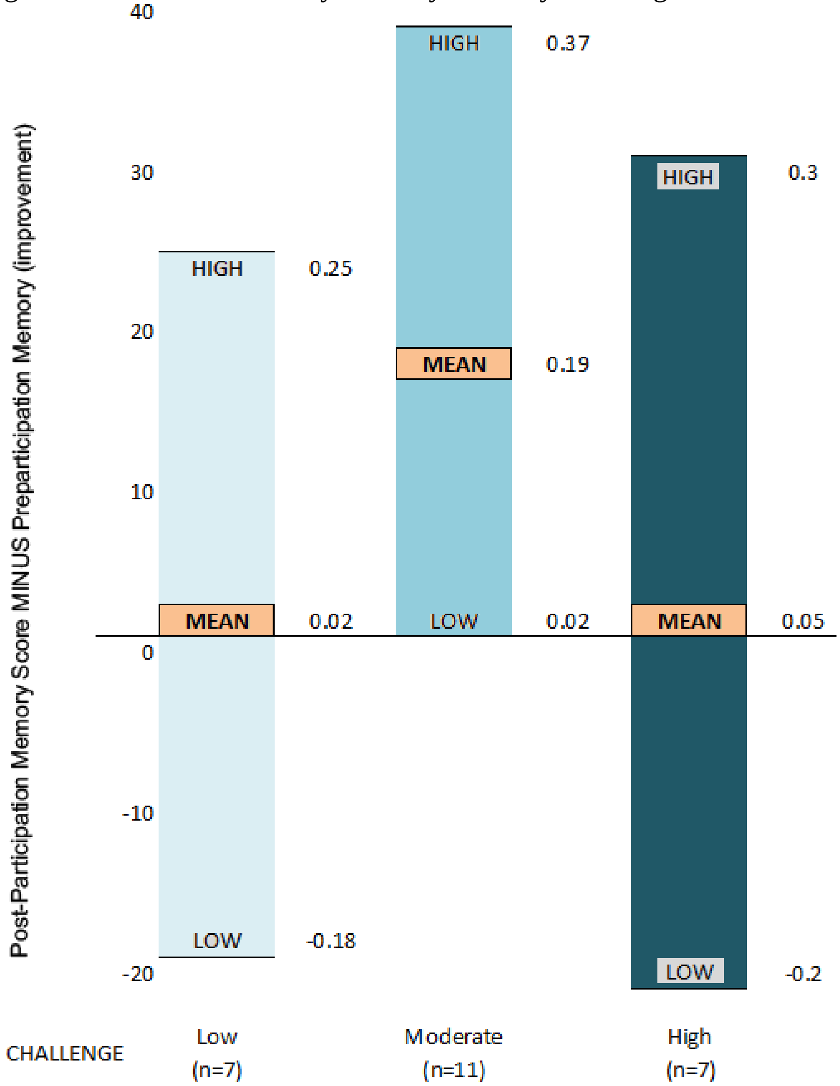
Self Challenge and Memory Benefits

The Cog State working memory test (CogState, 2008) was administered to participants before they began participation in the study and at the end of their 6 week participation. Memory scores improved for 56% of players, stayed the same for 24%, and worsened for 16% during the course of the 6 week study participation. Two of the 27 participants did not complete the entire post test, reducing the viable sample size for this analysis to 25.

Colum 8 of Figure 5 shows the average pre-post working memory test difference. The moderate self challengers appeared to show more consistent improvement, but the difference was not significant (p=.331). A basic premise of this manuscript is that degree of self challenge is likely to impact benefits of playing a brain game. If there is a relationship, it appears not to be linear. In other words, more challenge is not necessarily better. Perhaps moderate challenge is ideal. To further explore this possibility, we ran analyses contrasting moderate self challengers with everyone else (low and high self challengers).

Those who chose the easiest challenges tended to improve mildly if at all, about as much as those who chose the hardest challenges. (See Figure 6.) The moderate challenge group improved more than three times as much as any other group. A t-test was run to contrast Moderate players with Low and High challenge players (combined). The mean difference between moderate challenge players and the two extreme challenge groups approaches but does not achieve significance (t=-1.54, df=2,23, p=.138). If the finding is confirmed in other studies with larger sample or effect sizes, that means that a moderate amount of failure is optimal for brain games, and perhaps for enjoyable as well as effective game play.

Figure 6: Post Minus Pre-Play Memory Score by Challenge Orientation



Subtracting the pre-play memory score from the post-play memory score yields a measure of pre-post improvements. A value of zero indicates no difference. Negative numbers show worse memory performance at the end of the 6 weeks of play than before, whereas positive numbers show improved post-play memory.

Diversity of Brain Domain Play

Players tended to play more of the brain domains they were good at, and to play less of the brain domains they found more challenging. Figure 7 shows the distribution of diversified play across the five possible brain domains. A score of 100 represents six weeks of play evenly spread across the five brain domains. A score of 0 would be someone who spent all of his time playing only a single brain domain. Everyone tried each brain domain at least once, but 29.6% of players focused almost entirely on one or two domains. On the other extreme, 18.2% of players strongly diversified their play across brain domains.

Figure 7

Brain Domain Diversification

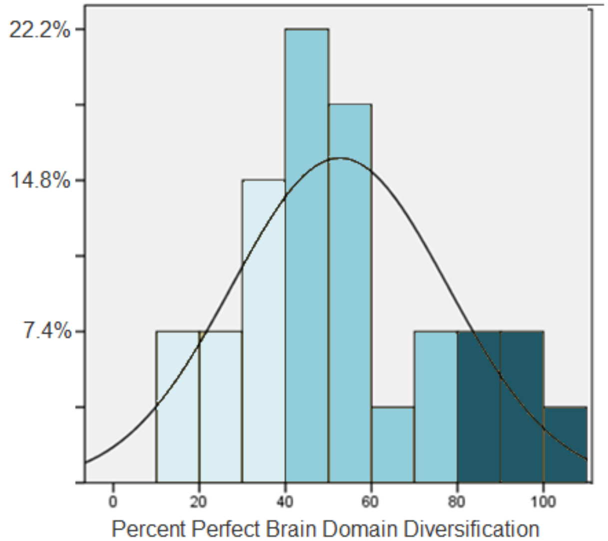
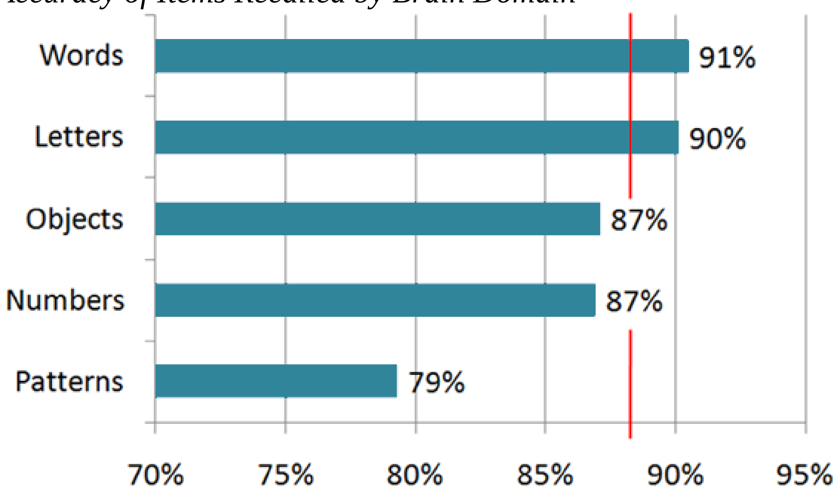


Figure 8 shows that items correctly recalled (accuracy) varied by brain domain. Words and letters showed the overall best average recall with an average accuracy of 90 to 91%. Patterns were the most challenging, with 76% of pattern items correctly recalled.

Figure 8
Accuracy of Items Recalled by Brain Domain

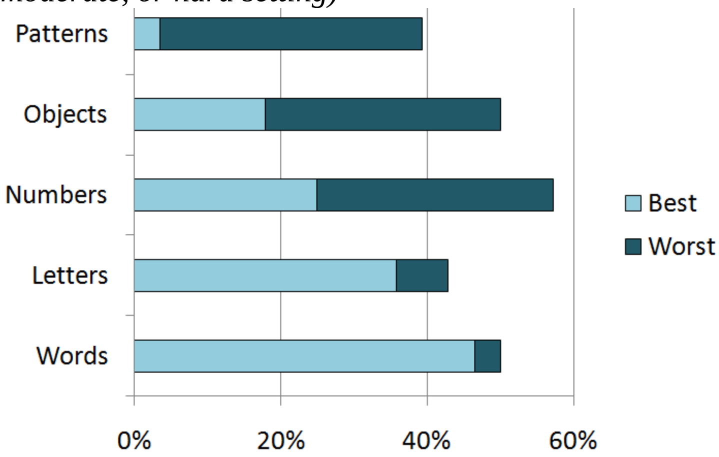


Some individuals were better at each brain domain than others are. (See Figure 9.) In this sample of 27 frequent players, short term WORD memory was the strongest ability for 46%, of players and the weakest ability for only 4%. Letters was the next most common strength, best for 36% and worst for 7%. Numeric short term memory and object short term memory were strongly split. Each brain domain was the strongest ability for 32% of players, but the weakest ability for a different 25% and 18% respectively. Patterns were the most overall difficult brain domain, worst for 36% and best for 7%. (Percent best and percent worst add up to more than 100% because domains could be tied for best or worse for any individual.)

Figure 9

Relative Ability by Brain Domain

(% of players for whom performance in a domain was their best and the % for whom performance in a domain was their worst, irrespective of whether play was at the easy, moderate, or hard setting)



DISCUSSION

Participants in this study were mature adults who volunteered to work at maintaining and improving their cognitive health. They are a prime audience brain games are designed to benefit. The participants were not selected because they are gamers, and they did not volunteer knowing they would be playing games.

About one fifth of Keep It In Mind players fit the profile of extreme challenge-seekers and another fifth fit the profile of extreme challenge-avoiders. The results reveal a natural tendency on the part of a subset of participants to choose modest challenges and to focus on one or a few brain domains that are easiest for them. Across almost all participants avoided trying to remember the full set of 7 items the game is capable of offering. They were least likely to receive the cognitive benefits that motivated them to play in the first place. These players fit the profile of how a Fixed mindset, challenge-avoiding person would play Keep It In Mind. We do not know whether they indeed enjoyed easy victories and avoided hard challenges to maintain a fragile self image of competency, or if they simply found easy victories relaxing.

The results also reveal a natural tendency on the part of a subset of participants to challenge themselves by selecting the hard difficulty setting, by remembering 5 to 7 items, and by pushing themselves to play quickly. These players fit the profile of how a Mastery mindset, challenge-seeking person would play Keep It In Mind. We had expected that group would be most likely to receive the cognitive benefits that motivated them to play in the first place. Instead, the results suggest that the in between approach to challenge may have resulted in more memory improvement than either Fixed Mindset (extreme challenge avoiders) or Mastery Mindset (challenge seekers). The finding is reminiscent of Csíkszentmihályi's concept of flow, the optimal combination of challenge and skill at any moment. Perhaps flow is good for brain exercise in addition to being good game design practice.

Individual abilities are diverse. Clearly treating all players as if they have equally powerful short term memory is not a sensible approach. Different brain domains are hard and easy for different players. Therefore, designing challenges based on the assumption that players are roughly the same is not a sensible approach.

Keep It In Mind may have given players too much freedom to set their own overt and enacted challenge, by enabling them to select a difficulty setting and further making it easy to replay easy levels and to start over without progressing up to 7 items. On the other hand, 7 items is too many for many players, so requiring success would not work.

There is some hope. People hold different mindsets for different activities. Most of us have realms in which we hold a Fixed mindset (the attitude, "I'm not good at this and I'll never improve") and Mastery mindsets in other realms. Furthermore, Dweck suggests that mindsets can change. She proposes that the nature of feedback and rewards can encourage or discourage a Mastery mindset (Dweck, 2006). This advice applies both in the classroom and in games. Brain games can be designed to emphasize brain growth goals (effort leads to improvement) and to subtly and overtly encourage players to view both the game itself and the cognitive domain it exercises as domains they can master.

The evidence of challenge-seeking and challenge-avoiding play styles found in Keep It In Mind may also have implications for game design beyond just brain game. It is possible and in fact even likely that these two player types can be found in most games.

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