IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

SHORT-TERM VISUAL MEMORY: CAPACITY AND REPRESENTATIONS

Jaba Varadwaj, Keka Varadwaj
Ph. D. Scholar, Lecturer in Psychology
Ravenshaw University, Utkal University

Introduction

In the history of early research on memory, William James proposed a distinction between primary and secondary memory pointing to the fact that primary memory are hold in the conscious present and secondary memory as stored outside of conscious awareness. These categories of memory actually resulted in the modern classification of short-term or working memory and long-term memory (Atkinson & Shiffrin, 1968; Scoville & Milner, 1957; Waugh & Norman, 1965). The most important distinction between the two memory systems lies in their capacity and nature of processing and storing information. Many researchers have pointed out that the working memory system has an extremely limited capacity of only a few items (Cowan, 2001; Cowan, 2005; Miller, 1956), whereas the passive, long-term memory system can store thousands of items (Brady et al. 2008; Standing, 1973; Voss, 2009) with remarkable fidelity (Brady et al., 2008; Konkle et al., 2010a). In fact, although research on human memory has long since identified these separate memory systems and stages of memory processing, those are not adequately educative about the nature of representations in the working memory system.

However, many recent researches on visual short-term memory has emphasized on its contents, capacity, format and structure of the information (e.g., Adams et al., 2017; Alloway & Alloway, 2010; Fukuda, Vogel, Mayr & Awh, 2010). The interaction between memory and vision is interesting because it concerns both the process of memory and the nature of the stored representations (Luck & Hollingworth, 2008). In fact, research on visual memory has pointed to a significant trade off between number of items and the precision with which each item is remembered. It is observed that as the number of items and/or the complexity in the resolution of the items in the visual field increases, the precision with which each item is remembered decreases and therefore, the performance of the visual short-term memory declines (Alvarez & Cavanagh, 2004; Wilken & Ma, 2004). In the research literature, it is referred to as the complex resolution hypothesis of the visual field. On the other hand, while some researchers have pointed to an upper bound of the number of items as capacity of the visual memory, (Alvarez & Cavanagh, 2004; Zhang & Luck, 2008), many others have also ruled out the upper bound hypothesis (Bays, Catalao & Husain, 2009; Wilken & Ma, 2004). Finding this gap in the research literature, the present study is an attempt to examine both the trade off theory or the complex resolution hypothesis and the upper bound theory of the visual memory processing.

Review of Literature

The visual working memory system is used to hold visual information actively in memory and to manipulate that information to carry out cognitive tasks (Baddeley, 2000). The study of visual working memory has largely focused on the capacity of the system and individual differences in the capacity of visual memory have been found to correlate with cognitive skills including fluid intelligence (e.g., Alloway & Alloway, 2010; Fukuda, Vogel, Mayr & Awh, 2010; Kane, Bleckly, Conway & Engle, 2001). This relationship suggests that visual working memory is a core cognitive ability to process information across cognitive domains. Thus, understanding the capacity of visual working memory could provide important insight into cognitive functions. Luck and Vogel (1997) conducted a pioneering study on the capacity of visual short-term memory, which reported that observers accurately detect changes in visual stimuli only when there are fewer than three or four items in the display. Thus, their results are consistent with a slot hypothesis of visual memory. However, other studies have pointed out that the resolution characteristics of the visual stimuli constitute an important factor in the capacity of visual memory (e.g., Rouder, Morey, Cowan, Zwilling, Morey & Pratte, 2008).

Although experiments using large changes following a change detection paradigm found evidence for a slot model, in which short-term visual memory is limited to storing a fixed number of items; subsequent experiments with refined paradigms that focused on the precision of memory representations have reported an information-limited model but not a slot model. In fact, Alvarez and Cavanagh (2004) proposed the information limit on working visual memory is a trade off between the number of items stored and the fidelity with which each item is remembered. When more number of items is stored, the fidelity of each item decreases accordingly. For example, if the visual memory capacity of a person is eight, he can remember eight bits of information about one object, 4 bits of information each about two objects, and two bits of information each about 4 objects. Hence, the results of the study pointed out that the number of items remembered is reciprocally related to the information load of the items. That is, the more information to be remembered for an individual item, the fewer the total number of items that could be stored with sufficient resolution, consistent with the hypothesis that there is a limit to the total amount of information stored.

Researchers have also tried to examine the nature of representations in the working visual memory. Beginning with Miller's (1956) classical study claiming a limit of 7±2 chunks as the capacity of working visual memory, several other studies have also reported on the limited capacity of the working memory by storing a fixed number of chunks, which decays over time (e.g., Baddeley, 1986; Cowan 2005; Cowan & AuBuchon, 2008). In visual working memory, this debate has focused largely on the issue of whether separate visual features (colour, orientation, size) are stored in independent "buffers," each with their own capacity limitations (e.g., Magnussen, Greenlee & Thomas, 1996), or visual working memory operates over integrated object representations (Luck & Vogel, 1997; Vogel, Woodman & Luck, 2001). The present study is an experiment in a natural setting to highlight on slot hypothesis, limited information hypothesis, and the hypothesis related to the complex resolutions of the visual field.

Method of Study

At present, working with the computer key board has become a passionate habit of every youngster and most of them are found to be very efficient in the use of this device. Arising from this observation, thirty graduate students who regularly use both computer and android mobile were randomly selected from a degree college as participants in the study. The study was designed in four conditions and the task of the participants in the study was to type the names of 30 animals using the computer key board under four different treatment conditions.

Condition I. It was designated as the Blind Condition in which the participants were asked to type the names of thirty animals (Appendix-1) when the experimenter auditorily presented the names of the animals. In this condition, each of the 26 alphabets in the key board was blocked from the vision of the participants by using stickers to cover the alphabets. The computer screen was also covered from the vision of the participants. The experimenter called out the names of the animals in the list one by one. As soon as she finds that the participant typed one word, she immediately called the next word in the list. The test was administered individually to each of the participants. The total time taken by each participant was recorded. The print out of the typed copy was also taken for each participant to calculate the errors committed by him or her. The errors were calculated as wrong letters typed in each of the places of the word. For example, if the word Wolf is typed as Sofl, then there are three errors as only 'o' has occurred in its right place. The first condition was completed on the day 1.

Objective: The objective of this condition was to measure the extent to which the performance of participants on the key board was influenced by their habit and practice with the key board.

Hypothesis: The performance of the participants would not be largely influenced by the habits and practice with key board.

Condition II. The second condition was called the Control Condition in which the alphabets were shown in their appropriate places on the key board. However, the computer screen was covered from the vision of the participants. In this condition, the participants were asked to type the same thirty names of the animals but the serial positions of the names in the list were randomly changed. The experimenter called each of the animal names one by one as soon as the participant typed a name in the key board. The test was administered individually to each of the participants and time taken by each participant to complete the list was recorded. The printouts of the typed copies were also collected to count the errors. The calculation of errors in this condition was also same as in the first condition. If a letter is not typed in its right place in the word, it was counted as an error. The second condition of the experiment was completed on day 2.

Objectives: The objectives of this condition were: (i) To find out the extent to which the short-term visual memory is the basis of performances on the key board. (ii) To find out how conveniently the participants used the 26 alphabets on the key board denying the slot hypothesis or the hypothesis claiming that visual short-term memory capacity is limited to the magic number 7±2.

Hypotheses: (i) Visual short-term memory is the major basis of performance on the key board. (ii) The short-term memory capacity can be more than 7±2 or as many as 26.

Condition III. This condition was called the Minimal Change Condition in which the complexity in the resolution of the visual field of the key board was increased by altering the positions of two letters on the key board using stickers. In fact, the places of 'T' and 'G' were interchanged as the thirty animal names consisted of 10 numbers of 'T' and 7 numbers of 'G'. The participants were asked to type the same 30 animal names but in a different serial order than in the first two conditions. The computer screen was also covered from the vision of the participants and like the prior conditions, the experimenter called the names of the animals one by one, as the participant typed the names. The test was also administered individually to each of the participants and time taken by each participant to complete the test was recorded. The printouts of the typed copies were also collected to count errors. However, in this condition the counting of errors was little different. Although, the places of 'T' and 'G' were interchanged on the face of the key board, actually there were no changes in the typed copies because the key board is connected to the computer by a program. Therefore, if 'T' and 'G' were typed in their right places, those were counted as errors. On the other hand, when other letters were not typed in their right places, those were counted as errors. The first kind of errors were called errors relating to complex resolution part of the visual field and second kind of errors were called errors relating to unchanged part of the visual field. This third condition of the experiment was completed on the 3rd day.

Objective: To examine the complex resolution hypothesis of the visual as related to the performance of visual short-term memory.

Hypotheses: (i) Complexity in the resolution of the visual field negatively affects the performance of the visual short-term memory. (ii) The effect will not be limited only to the changed resolution part of the visual field; it would also spread to the unchanged part of the visual field.

Condition IV: This condition was designated as the Moderate Change Condition in which the places of four letters R, H, S, and C were changed among them in an anti-clock wise direction using stickers. This condition was supposed to be twice as complex in the resolution of the visual field as in the third condition because four letters were changed in this condition as compared to two letters in the third condition and these letters occurred 34 times in the animal names as against 17 times in the third condition. In this condition, the participants were also asked to type the same 30 animal names but in a different serial order than in the other conditions. The experimenter presented words auditorily to the participants and the computer screen was covered. Like other conditions, performance time was recorded and printouts of the typed responses were obtained to count errors. In this condition, the error counting was similar to that of the third condition. The fourth condition of the experiment was completed on the 4th day.

Objective: To examine the effects of higher complexity in the resolution of the visual field on the performance of short-term visual memory

Hypotheses: (i) Higher complexity in the resolution of the visual field will increasingly affect the performance of the visual short-term memory. (ii) The increasing error in the performance will not be limited to the complex resolution part of the visual filed; it will also proliferate to the unchanged part of the visual field.

Results

Nowadays, every youngster is quite proficient in using the computer key board. Here, the interest of the study was to find out how the visual short-term memory helped their performance on the key board. The study consisted of four conditions, which are described in the method of study section. The materials used in the study were the names of 30 animals and all the participants were requested to rehearse the spelling of the animal names prior to the study. The experimenters ensured that all of them knew the correct spelling of the names. The names of the animals consisted of 158 letters in total using 23 of the 26 alphabets. The results of each of the conditions are described below and summary of the results are presented in Table 1.

Condition (i). It is called the Blind Condition in which the participants were required to type the names of the animal when stickers covered all the letters on the key board. In fact, the participants said that they did not remember the location of the alphabets on the key board and therefore they could be able to type the words properly. However, they were requested to perform the task saying that they could do it because of their long habit and practice with the key board. Finally, out of the 4740 responses (letters typed: 158x30) of the 30 participants, only 341 responses were correct, and on the average, they took 3.1 seconds to type an alphabet on the key board. The error rate in their performance was 92.81% (4740-341/4740 X100). Hence, performance of the participants was extremely poor without seeing the letters on the key board. Thus, the results clearly implied that even long practice and habit with the key board had no good effect on their performance

Condition (ii). Naturally, arising from the results of the first condition, the assumption was that the performance on the key board is a function of the visual short-term memory of the participants, which could be activated only by seeing the letters on the key board. Therefore, in the second condition (Control Condition) the normal key board was used with all the 26 letters shown in the appropriate places of the key board. To examine the function of visual short-term memory on the key board performance, the participants were asked to type the spelling of the same 30 names of the animals using the key board. However, the serial positions of the animal names were randomly changed in order to counter balance any practice effect from the previous condition. Similar to the first condition, the words were presented to the participants by the experimenters in an auditory mode. In this condition, only 22 out of the 4740 responses of the participants were wrong. Further, the average time of responding to an alphabet was reduced to 1.38 seconds and the error rate was reduced to only 0.46% (22/4740 X 100). Thus, the results pointed to two important things. Firstly, the performance on the key board was carried out by the help of working visual memory. Secondly, the upper bound hypothesis that magic number 7± 2 is the capacity of visual working memory was not supported in the study as the participants simultaneously attended to 26 items on the key board. Hence, the findings of the present study do not confirm the limited capacity hypothesis or slot hypothesis of working visual memory.

Condition (iii). In the third condition of the study called Minimal Change Condition, a complex resolution in visual stimulus presentation was introduced to examine the complex resolution hypothesis of visual field. In this condition, the places of only two letters, 'T' and 'G' were interchanged on the key board using two stickers of 'T' and 'G'. The objective of the change was to test whether there would be more errors in the performance of the participants due to the increase in the complexity of resolution of the visual field. In this condition, the participants were asked to type the same 30 animal names, their serial position in the list being randomly changed. Experimenters also presented the animal names in an auditory mode. In fact, there were 17 possible (T=10, G=7) situations where a participant can commit errors relating to 'T' and 'G'. Out of the total 4740 responses, 572 responses of the participants were wrong of which 476 errors were related to 'T' and 'G' and 96 errors were related to other alphabets. Hence, the overall error rate was 12.07% (572/4740x100), the error rate relating to the changed resolution part of the visual field was 10.04% (476/4740x100), and the error rate relating to the unchanged part of the visual field was 2.03% (96/4740x100). The average time of responding to an alphabet was 1.96 seconds. The results of this condition clearly supported the complex resolution hypothesis of the visual field as the error rate increased from 0.46% in the second condition to 12.07% in the third condition. Further, rate of error in the part of the visual field involving complexity in resolution increased from 0.46% to 10.04%, while the error rate in the rest part of the visual field not involving any change increased to 2.03% as against 0.46% in the second condition. Hence, the findings clearly supported the hypothesis that complexity of resolution in the visual field affects the short-term memory performance of the participants. Further, as the error rate also significantly increased with respect to the unchanged part of the visual field, such findings rejected the slot hypothesis because the impact of the complexity of resolution spreads into the total visual field and not only limited to the slot of the complexity.

Condition (iv). In view of the findings of the third condition, a fourth condition called the Maximal Change Condition was introduced in the study. In this condition, the places of four alphabets R, S, H, and C were interchanged in an anti-clock wise direction using four stickers. The objective of this condition was to examine how increased complexity in the visual filed affects the performance of the short-term visual memory. In this condition, the complexity of the visual field was increased twice as compared to the third condition because the places of four letters were changed as against two letters in the third condition and there were 34 occurrences of the letters in the list as against 17 in the third condition. The same thirty animal names were auditorily presented to the participants and they were asked to type them on the key board. The four alphabets were used 34 times in the words, (R=15, S=4, H=6 and C=9) and the serial position of the words were also randomly changed during presentation. In this condition, out of the 4740 responses 1436, responses were wrong of which 913 errors were related to the letters of changed positions and 523 errors were related to unchanged part of the key board. Per alphabet, average time was 2.03 seconds. Hence, the total error rate was 30.30% (1436/4740x100), the error rate relating to changed part was 19.24% (913/4740x100), and the error rate relating to unchanged part was 11.03% (523/4740x100). Hence, the overall error rate increased from 12.07% in the third condition to 30.30% in the fourth condition. The error rate for the changed part of the visual field increased from 10.04% to 19.24%, and the error rate for the unchanged part of the visual field increased from 2.03% to 11.03%. However, the per item response time has increased from 1.96 seconds to only 2.03 seconds. Hence, the findings clearly pointed out that increase in the complexity of resolution in visual filed increasingly affected the performance relating to visual short memory. The results further pointed out that with increased complexity in the resolution of the visual field, the performance decrease were not only confined to the part of the complex resolution, but also to the unchanged part of the visual field. Further, the unchanged part of the visual field was more affected than the changed part. The evidence comes from the fact that the performance decrease from third to fourth condition with respect to the complex resolution part of the visual field was only 91.63% (9.2/10.04x100), while the performance decrease with respect to the unchanged part of the visual field is 443.35% (9.00/2.03x100). Hence, the findings, rejects the slot hypothesis as the rate of error occurred more outside the slot and strongly approves the complexity of resolution hypothesis as increased complexity resulted in more errors.

Table 1. Condition-wise error rate in percent

Condition	Total	Complex Part	Unchanged Part
Blind Condition	92.81		
Normal Condition	0.46		
Minimal Change	12.07	10.04	2.03
Maximal Change	30.30	19.24	11.03

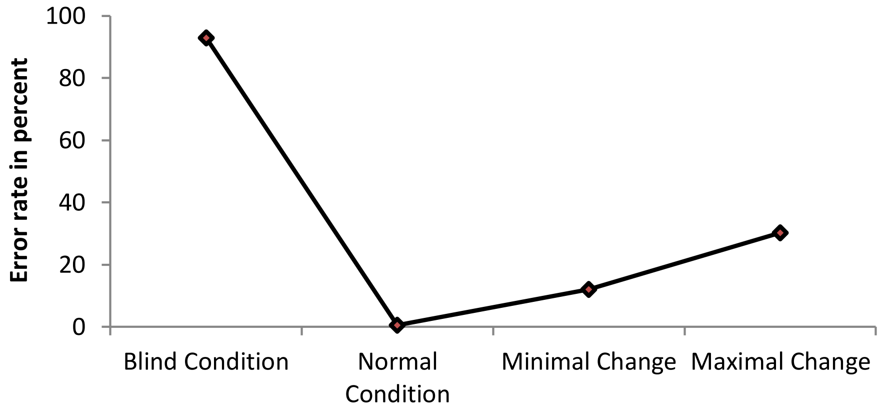

Figure 1. Showing the error rate of different conditions

Conclusion

Arising from the results of the present study, the following conclusions are presented with respect to the slot hypothesis and complexity of resolution hypothesis.

1. The performance on the key board of the computer is not a matter of habit or practice; it is a function of short-term visual memory.

2. The slot hypothesis that the magic number 7±2 is the capacity of the visual short-term memory is not true because the participants simultaneously surveyed 26 alphabets while typing the animal names.

3. The hypothesis relating to the complexity of resolution of visual field is strongly supported because increasing the complexity of resolution cumulatively increased the errors in performance.

4. Increase in the complexity of resolution of the visual field not only affects the complex part of the field but also the total visual field.

References

Adam, K. C. S., Vogel, E. K., & Awh, E. (2017). Clear evidence for item limits in visual working memory. *Cognitive Psychology*, *97*, 79-97.

Alloway, T.P. & Alloway, R.G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology*, 106(1), 20-29.

Alvarez, G.A. & Cavanagh, P. (2004). The capacity of visual short-term memory is set both by visual information load and by number of objects. *Psychological Science*, 15(2), 106-111.

Atkinson, R.C. & Shiffrin, R.M. (1968). *Human memory: A proposed system and its control processes.* In Spence KW, Spence JT, editors. The psychology of learning and motivation: Advances in research and theory. Vol. 2. New York: Academic Press; pp. 742-775.

Baddeley, A. D. (1986). Working memory. Oxford: Clarendon Press.

Baddeley, A.D. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences.* 4(11), 417–423.

Bays, P.M., Catalao, R.F.G. & Husain, M. (2009). The precision of visual working memory is set by allocation of a shared resource. *Journal of Vision*, 9(10), 1-11.

Brady, T.F., Konkle, T., Alvarez, G.A. & Oliva, A. (2008). *Visual long-term memory has a massive storage capacity for object details.* Proceedings of the National Academy of Sciences, 105(38), 14325–14329.

Cowan, N. & AuBuchon, A.M. (2008). Short-term memory loss over time without retroactive stimulus interference. *Psychonomic Bulletin & Review,*15(1), 230–235.

Cowan, N. (2005). Working memory capacity. Hove, East Sussex, UK: Psychology Press.

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences*, 24, 87-185.

Rouder, J.N., Morey, R.D., Cowan, N., Zwilling, C.E., Morey, C.C. & Pratte, M.S. (2008). *An assessment of fixed-capacity models of visual working memory.* Proceedings of the National Academy of Sciences, 105(16), 5975–5979.

Fukuda, K., Vogel, E.K., Mayr, U. & Awh, E. (2010). Quantity not quality: The relationship between fluid intelligence and working memory capacity. *Psychonomic Bulletin and Review.* 17(5):673-679.

Kane, M.J., Bleckley, M.K., Conway, A.R.A. & Engle, R.W. (2001). A controlled-attention view of working-memory capacity. *Journal of Experimental Psychology: General*, 130,169-183.

Konkle, T., Brady, T.F., Alvarez, G.A. & Oliva, A. (2010a). Scene memory is more detailed than you think: the role of categories in visual long-term memory. *Psychological Science*. 21(11), 1551–1556.

Luck, S.J. & Hollingworth, A. (1997). Visual Memory. New York: Oxford University Press.

Luck, S.J. & Vogel, E. K.(1997). The capacity of visual working memory for features and conjunctions. *Nature*, 390, 279–281.

Magnussen, S., Greenlee, M.W. & Thomas, J.P. (1996). Parallel processing in visual short-term memory. *Journal of Experimental Psychology: Human Perception and Performance*, 22(1), 202–212.

Miller, G.A. (1956). The Magical Number Seven, Plus or Minus Two: Some Limits on our Capacity for Processing Information. *Psychological Review*. 63, 81–97.

Scoville, W.B. & Milner, B. (1957). Loss of recent memory after bilateral hippocampal lesions. *Journal of Neurology and Neurosurgery and Psychiatry*, 20, 11–21.

Standing, L. (1973). Learning 10,000 pictures. *Quarterly Journal of Experimental Psychology*, 25, 207–222.

Vogel, E.K., Woodman, G.F. & Luck, S.J. (2001). Storage of features, conjunctions, and objects in visual working memory. *Journal of Experimental Psychology: Human Perception and Performance*, 27:92–114.

Voss, J.L. (2009). Long-term associative memory capacity in man. *Psychonomic Bulletin & Review*, 16(6), 1076–81.

Waugh, N.C. & Norman, D.A. (1965). Primary memory. *Psychological Review*,72, 89–104.

Wilken, P. & Ma, W. J. (2004). A detection theory account of change detection. *Journal of Vision*, 4, 1120–1135.

Zhang, W. & Luck, S. J. (2008). Discrete fixed-resolution representations in visual working memory. *Nature*, 452, 233–235.

Appendix-1. Names of 30 animals and number of used in all these words

Cat	Giraffe	Parrot	N=07	A=16
Dog	Frog	Panda	O=12	B=02
Lion	Turtle	Chicken	P=05	C=09
Bear	Wolf	Cheetah	Q=01	D=07
Deer	Squirrel	Crocodile	R=15	E=20
Horse	Bat	Penguin	S=04	F=04
Snake	Owl	Camel	T=10	G=07
Tiger	Leopard	Duck	U=04	H=06
Cattle	Goat	Hyena	V=00	I=09
Sheep	Gorilla	Lizard	W=02	J=00
			X=00	K=03
			Y=01	L=12
			Z=01	M=01
44	53	61	62	96 Total=158