

Multisensory Design in Memory Research: The £1 Coin Case in the Digital Era

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Abstract. This study explores the effects of multisensory memory on memory for everyday objects, with a particular focus on memory for £1 coins. The study delves into the intersection of sensory anthropology, sensory history, and sensory sociology to examine how multisensory experiences affect memory persistence. The study used a dual-task paradigm and cross-modal stimuli to investigate the effectiveness of different sensory combinations in enhancing memory. Post-epidemic era, unlike offline experiences, this experiment utilised an online survey and a variety of media formats including text, images, video, audio and physical objects. The results showed that multisensory interactions significantly improved short-term memory recall over single-sensory modalities, while visual elements such as colours and shapes had a lasting effect on long-term memory. The study also highlights the potential of multisensory engagement in educational environments and museum experiences, gathering reliable data for future projects in which computers simulate human behaviour.

Keywords. Human factor design, Multisensory memory, Cognitive interdisciplinarity, Museum visitor experience, Human behaviour

1. Introduction

Memory research, with origins in ancient Greece and Rome, has become interdisciplinary, focusing on sensory memory and integrating perspectives from social sciences and humanities [1][2][3][4].

Sensory experiences combine multiple senses, yet working memory research often targets single modalities [5]. Traditional studies also focus on single-modality stimuli for memory and recognition [6]. For instance, superimposing photos on numbers in tasks can strain visual attention, affecting memory if the image is ignored, highlighting auditory recall's superiority over visual [7][8]. Recent words in sentences are better remembered, aiding recall of the entire sentence.

Broadbent et al. [9] noted that multi-sensory learning enhances retention compared to single-sensory cues. Nairne et al. [10] found that tangible objects are better remembered than non-tangible ones, with animation aiding recall. Delogu et al. [11] showed audio-visual stimuli lead to improved recall over auditory or visual alone in nonverbal contexts, and that this advantage persists in verbal contexts for audio-

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visual versus visual stimuli. Their findings align with Baddeley & Andrade's [12] model, where the episodic buffer consolidates multi-modal information with semantic details from long-term memory.

Multi-sensory memory enriches perception, surpassing single-sensor models [14]. Thompson and Paivio found cross-modal audio-visual stimuli enhance recall over unimodal stimuli. Goolkasian and Foos [15] observed better memory for objects initially processed through an unrelated sense in old/new recognition tasks [16]. Dual-task experiments, distinguishing between interference and learning tasks [17], confirm working memory's componential structure, showing performance drops when tasks compete for the same memory resources [18][19].

Traditional memory studies focused on single-modality stimuli, but real-world object recognition often involves multi-sensory processing [17]. Research shows people often overestimate their understanding of familiar objects [20]. Advances in psychology, neurophysiology, and brain imaging have enhanced our grasp of cognitive processes and memory, especially in everyday multi-sensory contexts [21]. Multi-sensory experiences significantly alter behavior, perception, and brain activity, influencing memory. Tests reveal that auditory-visual processing leads to better memory retention compared to single-sensory conditions [6].

Our study focuses on challenging and comparing the proportion of single-sensory and multi-sensory memory recall. Memory recall after multi-sensory interaction was conducted by following an experimental approach of a dual-task paradigm. In a field where design and cognitive disciplines intersect, it is hoped that learning about memory will lead to a greater understanding of participants' memory patterns and behaviours and thus to a more detailed understanding of visitor behaviour, memory, etc., in future museum visitor experiences.

2. Experiment 1: Generally Understood: Who were not Told What the Study was Testing

2.1. Method

To find a better way of online experiments, our experimental methods were inspired by Lawson [20]. All participants conducted this experiment on the £1 coin through questionnaires. At the beginning of the investigation, they need to prepare pens and notebooks. The questionnaire has three sections: personal questions, rate yourself and compulsory selection. In the "personal question" section, in addition to some basic questions (age, gender, time in the UK, nationality, which handwriting is preferred), participants were also asked to answer the payment method and the frequency of using cash. Next, in the 'rate yourself' section, the participants are asked to estimate their knowledge about the £1 coin in a total of five evaluation levels, from 'very bad' to 'excellent'. They were then asked to try to draw £1 coins relying on their impression on paper. Finally, in the compulsory selection (see Figure 2), the question will be about all the features of the £1 coin. Each question will give them different options and then choose the correct answer, which checks the drawing error. It is not just because of sketching problems or scoring drawing errors. The survey takes about 4-5 minutes to complete (if they can draw pictures on paper); they are only told that the survey is related to familiar objects in life.

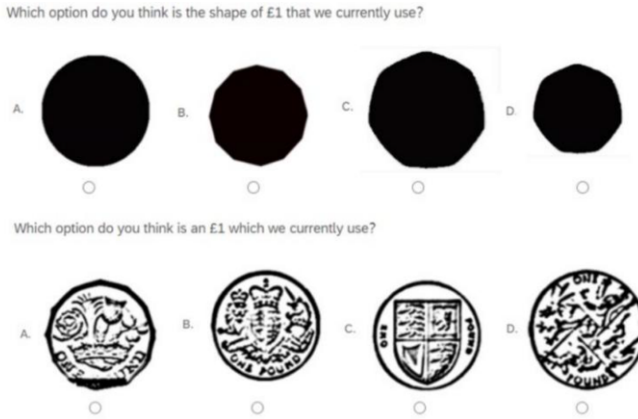


Figure 1: Different versions of £1 coins and shapes are added to the options. Allowing participants to choose the correct pattern, which proves that drawing will not have any false impact on memory and will not be confused with hand-drawn memories.

2.2. Participant

Two hundred and four participants (62 males and 142 females) were found randomly at Cranfield University. The age of 83.82% comes from between eighteen to forty-four. One hundred ninety-two participants reported being right-handed, and ten participants used left-handed. All the responses were collected online via Qualtrics Survey software; a few sent their drawing sketch to me by email.

2.3. Result

The experiment was conducted during the lockdown period in the United Kingdom, and the life involved will change, and online shopping became the mainstream. Therefore, to ensure that participants continued using cash or coins during the lockdown period, this study investigated the payment methods. 57.76% of people will use cash and credit cards, 22.55% will be used to using a similar PayPal form of input payment, and 16.18% are the only credit card used. The survey results confirmed that at least 61.27% of the participants would be exposed to the £1 coin in their daily habits; coins are indeed everyday items in life. In the self-assessment of the survey's knowledge of the £1 coin, 55.39% of the participants said they did not know at all, and only 1.96% said they knew very well and knew a lot. Simultaneously, it shows that although most people use these ordinary things every day, they may have an impression, but most of them are very vague and will not over-observe the things themselves. Although only a few participants made drawings in the sketching session, some feedback will be obtained from these participants. For example: 'I have been in the UK for many years, and I cannot remember what a coin looks like' or 'I seem to know its shape, but I am not sure; I need to reconfirm it.

In the last part of the compulsory selection (Table 1), participants make a preliminary selection of the £1 coin through pictures and textual options. 65.69% of the participants chose the correct answer by choosing the silver coin's shape. In comparison, 34.31% of the participants still chose the wrong answer for selecting the pattern on the

coin, 48.53%, which is close to the average participant's selection error. Questions about the coin's material will be answered incorrectly in more cases, reaching 54.90% of the participants.

Table 1: The total number of participants responding to the third section's in four questions. The option 'S&C' in the last 'Material' represents 'Silver and Copper'; 'S&G' represents 'Silver and Gold'.

Rate your knowledge about UK coin					
Rank	Great 2	A lot 2	Medium 28	A little 59	Not at all 113
1 pound shape					
Option	A (Round)	B(Correct)	C (6 sides, big size)	D(6 sides, small size)	
	43	134	15	12	
Pattern					
Option	A(Correct) 105	B 61	C 28	D 10	
Material					
Option	Sliver 23	Copper 13	Gold 37	S&C 40	S&C(Correct) 92

3. Experiment 2: Short-term Memory (Text and Pictures as Media)

3.1. Method

In addition to the within-subjects factor of the coin, the between-subjects study time and disturb time were included in the present experiment. The experiment method was the same as experiment 1; all participants must fill out the redesigned survey through Qualtrics online. The redesigned survey is divided into four parts, and the first two parts have the 60s and 30s timing, respectively. In the first part, all participants have the 60s to study a paragraph of text and pictures introducing £1 coin, and then a 30s interference time. During these 30s, other coins information will be displayed in front of participants and read. When the time is over, the participants will answer the seven questions about the £1 coin that has been redesigned. Finally, answer personal questions (gender, age, nationality, etc.).

3.2. Participants

Two hundred and twelve participants (83 males, 118 females and 11 people unwilling to tell their gender) were found randomly in Cranfield University and British society. 75.94% of the participants in this experiment are between 18-44 years old, and the others are from different age groups or even older participants, but this does not affect the experiment's results.

3.3. Result

In experiment 2, two methods of text description and image stimulation were used to test participants' STM after fixed learning time and interference time. In the questionnaire, many questions will be related to the characteristics of the 1-pound coin, which have been shown in the text introduction. As shown in Table 2, the accuracy of questions 1, 2, 3 and 4 are all above 50%. In general, in this group of experiments,

participants' judgment rate did not decrease due to the interference of 30 seconds. The results of the multiple-choice question for question 5 (Table 3) cannot be analysed accurately because we provided too many choices (4 out of 8 correct) to make a valid scientific analysis possible. We found that some participants could choose all four options completely correctly or that participants' choices were so scattered among the eight options that they could not be counted effectively, so that the question could not provide correct information.

In this experiment, we found that for STM memory recall of participants, the combination of sensory interaction of language (text) and visual (picture) was effective. Even if we added 30 seconds of interference in the teaching process, it would not affect participants' memory retrieval of text and picture content. Usually, some STM tests are used for education and teaching, as our experimental process is actually a kind of teaching. However, if the visitor interacts with the artifacts in the exhibition, this is actually similar to our experimental process, which also involves the visitor's STM. In addition, in the exhibition, some exhibitions will have a summary of the stages of the exhibition, so that visitors can understand the story of a period through the text. The purpose of our experiment is to test the STM of visitors through the information teaching of text and pictures. Such a setup (experiment) is what visitors would do in an exhibition. The data from this experiment will be compared with the data from subsequent experiments.

Table 2: The percentage of questions in Experiment 2. Each question has different choices for the question about the characteristics of the £1 coin in Experiment 2. Finally, we define it as the percentage of people who answered correctly and incorrectly so that the gap can be better seen.

Experiment 2			
Initial memory			
Question	Correct	Incorrect	
Q1- What is its shape?	52.83%	47.17%	
Q2- What is its thickness?	59.91%	40.09%	
Q3- What is its maximum diameter?	58.02%	41.98%	
Q4- What is its colour?	61.79%	38.21%	
Q7- What version of the coin portrait is it?	36.79%	63.21%	

Table 3: Questions about the characteristics of the £1 coin in Experiment 2.

Experiment 2					
Initial memory					
Question		Answer			
Q5- Which of the following flowers does its own?	League	Thistle	Shamrock	Rose	
Q6- Do you know which company made it?	46.23%	57.08%	54.72%	50.94%	
	Yes	Maybe	No		
	34.43%	50.00%	15.57%		

4. Experiment 3: Research from STM to Long-term Memory (Video, Audio, and Objects as Media)

4.1. Method

In Experiment 2, we tested the comparison of the degree of memory recall of after 60s timed learning through reading and pictures. In this test, the learning time was still reserved, but the time for a video reason was increased to 90s, but this time the media was video, audio and physical media, and the visual, auditory and tactile senses were

enabled. The experiment is divided into two stages: the immediate recall of memories, and the second recall of memories to the same participant two weeks later.

At the beginning of the experiment, participants were told in advance to prepare a £1 coin but were not told why. Then on the day of the test, we download a 1 minute 30 second introductory clip of the 1-pound coin from the Royal Mint's official website. The video is a detailed introduction to the 1-pound coin. After watching the video, participants were allowed to observe the coins in their hands for no longer than 30 seconds. Finally, fill out the same questionnaire as Experiment 2. In the second stage, after two weeks, the participants filled out the same questionnaire as the first experiment and performed a second memory recall. There is no learning time; just answer the questions directly. The questions are basically the same, with individual changes.

4.2. Participants

One hundred and thirty-five participants (43 men, 66 women, and 26 people who did not wish to report their gender) were found at Cranfield University and the Milton Keynes Chinese School and Community Centre. In Milton Keynes Chinese School, most of the participants are around 9-18 years old, and some adult students are local Chinese loving students.

There are two stages in this experiment, it is necessary to investigate and track the participants, so the experiment was finally conducted in certain classes of Cranfield University and Milton Keynes Chinese School. In this way, it can be determined that the experiment's quantitative results are accurate, and all come from the same fixed group.

4.3. Result

In the third experiment, participants mainly used images, sound and touch to understand the 1-pound coin and then conducted a questionnaire experiment. The progress rate of question response is basically above 50%. Compared with experiment two, the value is higher than that in experiment two. Regarding the fifth question, the recognition of flowers is still not very high, but the correct rate is basically around 50%. Regarding question 6, 60 participants expressed that they knew the name of the company with certainty. Among them, 47 wrote down their answers, and 10 were wrong answers.

After the first memory recall, we performed a second memory recall on the participants two weeks later. In the second experiment, no time was given to participate in any learning, and the same questionnaire was filled out. The only difference was that the question asked whether the participant had carefully observed £1 again after completing the first test. In the end, only 33 participants made observations of £1 again, and the rest of the participants were completely absent from our initial memory in this experiment. Two weeks later, we made a numerical comparison of the memory recall (see Table 4) and using it as a number or text option; the memory will be relatively attenuated for the memory of similar images, colours, shapes, for example, questions No.1 and No.4.

Finally, in the process, some participants said: 'Some of the content has been forgotten; it may be silly'; 'Some are somewhat impressed, but not sure'; or 'I

remember it'. Even after finishing the work, some participants follow up one after another for a few weeks in the experiment, and some people will replace the coin-related articles and write us to say: 'Up to now, some problems are still very accurate.'

Table 4: The percentage of correct answers by participants in the two stages, in experiment 3

Question	Initial memory	Two-weeks later
	Correct	Incorrect
Q1- What is its shape?	94.07%	84.44%
Q2- What is its thickness?	82.22%	52.59%
Q3- What is its maximum diameter?	82.96%	54.07%
Q4- What is its colour?	89.63%	79.06%
Q7- What version of the coin portrait is it?	60.74%	35.56%

5. Discussion

Experiment 3: Research from STM to Long-term Memory (Video, Audio, and Objects as Media)

Overall, the study objectively measures people's understanding of everyday objects (i.e., £1) through sensory interaction experiences. The reason for using a £1 coin as the medium for the experiment is that we have previously learned information about the history, printing, editions and so on of notes and coins from our observations at the Bank of England Museum, while the history of the currency is also available on the Royal Mint's website. We believe that £1, as the currency currently in circulation, has the significance of both a museum piece and an everyday object. In the experiment, it was easy for the participant when we asked the participant to prepare a coin. Simultaneously, for the first test, we asked participants to evaluate their knowledge of the coin and select the characteristics of the British pound coin that they deemed appropriate from the prescribed options. Most participants have errors and omissions in their understanding of the coin. It can also be seen from some participants' performances in the picture that the characteristics of the coin part are not prominent. Even for frequently encountered and easy-to-understand information, most people have a rough understanding of the concept of familiar everyday objects. The little or even inaccurate evidence for understanding causality is inconsistent with the robust version of the classification theory based on interpretation. The test in Experiment 1 only gives us a preliminary understanding that most people have a relatively weak knowledge of coins.

In the following experiments, we followed the traditional dual-task paradigm experimental method, which is the experimental method of studying working memory. However, the difference is that we added cross-sensory stimulation conditions. Different from other single-sensory memories (such as vision and hearing), the stimulus recall rate of multi-sensory cross-mode is higher than that of single-sensory. In the second experiment, we mainly used pictures and text to stimulate learning time and interference time, let the participants remember all the coin characteristics, and then immediately through the call. The data shows that more than half of the participants can get correct feedback. Then in Experiment 3, we changed the stimulus conditions to video and audio, and under the same other conditions, the participants were recalled immediately. Comparing the short-term memory data in Experiment 2 and Experiment 3 (see Table 5), it is evident that the accuracy of the audio-video-tactile recall in Experiment 3 is higher in the correct answer to each question.

Table 5: Comparison of the accuracy of questions in Experiments 2 and 3

	Experiment 2	Experiment 3
	Correct	Initial Correct
Q1 – What is its shape?	52.83%	94.07%
Q2 – What is its thickness?	59.91%	82.22%
Q3 – What is its maximum diameter?	58.02%	82.96%
Q4 – What is its colour?	61.79%	89.63%

Two weeks later, we conducted a second memory recall for the participants who had undergone auditory-visual-tactile stimulation in Experiment 3. We found an interesting phenomenon (see Figure 3). The data shows the memory recall after two weeks. The correct rate was higher than the picture-word memory rate in Experiment 2, especially when the questions involved colours, shapes, Etc. The correct rate of memorisation was very high. The picture's meaning is closely related to the content, but people do not remember all the details because they have no practical meaning. A coin is a meaningful object, but the specific details that appear on the coin and the interrelationship or spatial relationship between these details are of great significance [23]. People find that people's perceptual memory of everyday objects such as coins and road signs is surprising [23]. However, when it comes to memory recall with numbers or words in the options, the results obtained are relatively low or the same. People's memories of specific numbers are not very clear, and this may be because image memory is more stimulating than text memory.

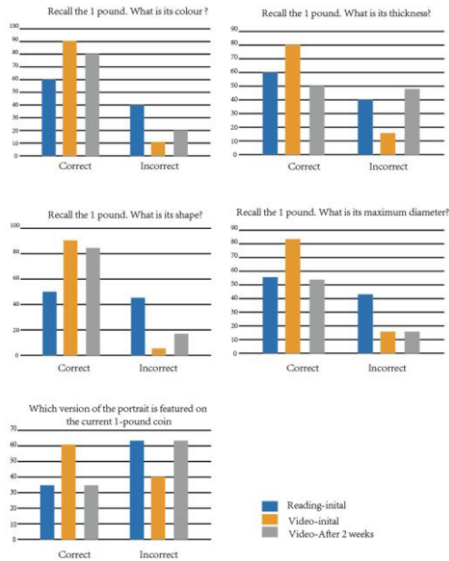


Figure 2: Histogram comparison of question correctness

6. Result

One hundred and thirty-five participants (43 men, 66 women, and 26 people who did not wish to report their gender) were found at Cranfield University and the Milton Keynes Chinese School and Community Centre. In Milton Keynes Chinese School, most of the participants are around 9-18 years old, and some adult students are local Chinese loving students. This experiment can be roughly divided into two age groups,

9-17 years old and 18-34. The whole experiment received about 2000 responses, and the results were analysed according to the questionnaire responses of staged experiments. The results showed that multi-sensory interaction evoked more memory for objects than a single visual sense for short-term memory. However, from the perspective of long-term memory, something more visual such as a colour or shape left a strong impression on participants. For more detailed textual descriptions, memories fade over time. This memory experiment was primarily an experimental memory experiment on a museum exhibition space, incorporating the sensory interactions of visitors. Imagine an experiment with a pound coin interacting with one of the artworks in the exhibition. Some artworks in the current exhibition fail to impress the viewer because the exhibit has no physical contact with the viewer. Another phenomenon that is also very interesting is that it is often thought that taking pictures of artwork helps to deepen memory. However, the objects could not remember the specific content of the pictures shortly after viewing them. Visitors did not immediately think of information about a particular exhibit after visiting all the exhibits, but only the most interactive and impressive exhibits during the tour. Although these studies reveal essential discoveries, there are also limitations. Because all memory tests are conducted through the Internet during a particular period, there are three shortcomings. First, it is impossible to determine whether the participants are cautious regarding touch. Observed the object. Second, there is a timing link in the interference phase in Experiment 2, and it is impossible to accurately determine whether the participant has completed the 30-second interference time. Finally, in the first experiment, we hope that participants will draw a pound coin in the form of a drawing.

Studies have shown that painting can improve daily and educational memory [24]. However, due to the limited conditions, we could not provide much feedback on the drawing online, so the project did not progress well. The experiment was divided into short-term memory (image-text); Short-term memory (video-audio-text object) and long-term memory (video-audio-text object). During the comparison process, the long-term memory data may be more complete if long-term memory (image-text) is also recorded in experiment 2. This study hopes to add knowledge of cross-cognitive disciplines to museum learning through in-depth research on working memory, to create better visitor experience and learning. This study hopes to bring cross-cognitive disciplines into museum knowledge and combine them through the study of working memory, to create better visitor experience and learning methods. In future studies, we will continue to focus on visitors' working memory and then study the relationship between visitors' memory recall and exhibits in computer simulation.

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