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Are Change Detection Tasks Visual Specific in Nature? An Investigation of Dual Task Methods

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Abstract

More recent working memory models consider visual representations constrained within components of the visual-specific architecture. However, in the visual patterns test, a multi-component approach with multiple can be used due to the use of verbal and semantic processing abilities within the task. The current investigation aimed to identify the extent to which visual and verbal types of information can contribute to visual working memory representation use. Within 2 experiments, 30 participants (5 males, 25 females) were used in an experiment where a dual task methodology was deployed, consisting of interference tasks presented during the 4 second maintenance phase of the procedure of the primary visual memory tasks. Results of these investigations indicated that a change in the conventional visual-specific approach may now be accepted with verbal interference effects being present in all primary change detection protocol tasks. The results will be discussed in the context of theoretical perspectives which emphasize modality specific nature of representation use versus multi-component perspectives which suggest a more domain general semantic strategy use.

Keywords: Change detection; Quantitative; Qualitative; Dual task

Introduction

Two contrasting perspectives of visual working memory capacities give clear explanations of how individuals can store visual array items in memory. The discrete slot account, as suggested by Luck et al. [1] explains working memory capacity in terms of a limited amount of information stored, with each item of information being stored in an individual slot. Luck et al. and Cowan N [1,2] evidenced that 3-4 memory items could be stored, for example, one item per slot. Another perspective focused upon a dynamically distributed memory resource which is distributed to all items within a visual array [3]. This account, known as a shared resource account, proposes no capacity limit to working memory and instead suggests a resource distribution where an increase in the number of items stored in memory, would ultimately results in a lower precision of these items. The current study will be underpinned by the current working memory capacity models.

Tasks such as the Corsi block task [4,5] and the VPT [6,7] have been used to investigate visual working memory capacity. Tasks using change detection procedures, such as those used in [1] original paradigm have been successfully used with older and younger adults as well as children as young as 3 months old [1,8-10]. In these tasks, an array of squares is presented, and at retrieval the individual must decide if a colour change can be detected. Tasks such as this can be defined as quantitative working memory protocols due to the detection of larger changes in visual arrays. More recently a different type of visual working memory task has been used to investigate changes in visual arrays which are much smaller in nature. Examples include the finite size changes of a shape. These tasks, such as those suggested by Phillips et al. [11] and Hamilton [12] are known as qualitative visual memory protocols and are an adapted version of the original change detection procedure. Within such paradigms, a display of one square is presented and when a second square is presented, the individual has to decide if the square is bigger or smaller than the first square presented. Bae et al. [13] developed a similar type of task, using two different encoding shapes to look at how features are stored within memory. The current investigation will develop a methodology using these ideas.

Many working memory models can be used to explain the functional use of working memory during specific tasks. In early work, Baddeley et al. [14] suggested the distinction of components within visual working memory, with a phonological loop to control and rehearse verbal material, and a visuospatial sketch pad to store and rehearse both visual and spatial material. An update of this original account Baddeley [15,16] introduced the central executive as a component to control and relay information in and out of these two slave systems within memory. The distinction of these visual and verbal components proposed that all visual working memory tasks would use the visuospatial sketchpad to store information and that there would be no influence of verbal based components within the architecture. Luck et al. [8] recently supported the suggestions made from Baddeley [15,16] in indicating that a visual working memory task must maintain the utilization of visual material only. There will be no influence of a phonological loop type component and verbal semantic use is not present. Research from Shah et al. [17] evidenced the domain-specific perspectives of visual working memory by showing no relationships between spatial span and reading span task measures, indicating that visual and spatial working memory can be explained in terms of separate functioning systems for visual and verbal aspects of information.

However, the multi-component approach by Logie [18] has offered an alternative explanation, with the introduction of an episodic buffer component to combine the use of visual and verbal material. Baddeley [16] had suggested that while completing a visual memory task,

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individuals send information directly into the visuospatial sketch pad on a perceptual level, with no links to the slave systems within memory. Logie [18] proposed the opposite of this suggestion by stating that information is passed through an episodic buffer component before reaching any information specific component. The episodic buffer was designed to control the direction of the information use; however, this component was evidenced as not visual specific. The component integrated the visual information, verbal information and aspects of long-term semantic memory within a visual memory task.

Hamilton [12] on the other hand investigated at the use of qualitative visual memory tasks in contrast to the original quantitative tasks developed by Luck et al. [1]. The type of task discussed was known as the size just noticeable differences. Hamilton [12] suggested that these types of tasks rely heavily upon an individual visualizing the material they are presented with. Representations of this nature are ones which are visually and perceptually driven and therefore cannot be supported using long term memory or semantic strategy use as previously discussed from Brown et al. [19]. This is one debate of which the current investigation will help in answering. Are change detection tasks visual specific as proposed by Hamilton and Luck et al. [8,11], or can researchers adopt the more widely used multi-component approach which has previously been used to discuss the VPT [18,19]?

The visual patterns test has been used to look at the representation use within visual working memory tasks. Hamilton et al. [12] supported the multi-component as suggested by Logie [18], by demonstrating verbal and executive interference effects within a Visual Patterns Task using a dual task approach. Hamilton et al. [12] studied this within children and adults during their investigations. Brown et al. [19] also presented similar findings with the use of the visual patters test. In this procedure, it was demonstrated that an executive interference task such as spatial tapping eliminated the advantage of a condition which was seen to have high verbal coding. Brown et al. [19] concluded that the visual patterns test did not use a phonological loop component as such; however, an executive resource was at use which allowed the use of semantic material. In an electrophysiological study, Riby et al. [7] used the visual patterns test to propose the less visual specific nature of visual working memory tasks. Work was supported by the increased activity of the semantic N400 in the verbal condition which asked participants to use verbal strategies when encoding the visual stimuli presented.

Similar results had been produced from Rudkin et al. [20] who made suggestions about the Corsi blocks task, colour memory tasks and the VPT, supporting Baddelely [16] in the visual specific suggestions. Vergauwe et al. [21] used a dual task approach to investigate visual and spatial separation visual and spatial memory tasks. Vergauwe et al. [21] demonstrated that visual memory tasks can use both visual and spatial types of information at the same time, with the interference of both spatial and visual secondary tasks.

As Luck et al. [8] had indicated that visual tasks are visual specific only, the suggestions from Logie [18] and Brown et al. [19] oppose this and provides the current study with a reason to investigate whether the visual specific approach can be applied to all other visual tasks. Only a small amount of empirical research focuses upon the functional architecture associated with visual change detection tasks, therefore the current investigation will use two versions of change detection protocols (as discussed below) as comparison of their working memory architecture development and use. Experiment 1, containing the first change detection task, will use an adaptation of the original paradigm from Luck et al. [1] whereby coloured squares are to be remembered. This change detection protocol will be known as a quantitative measure since the task assesses the memory of large colour changes in a visual array. Experiment 2, utilising a second change detection task will aim to detect shape size changes and will be created using similar protocols discussed by Hamilton [12] and Bae et al. [13]. This task will be known as a qualitative change detection task since it measures the small finite details of shape size changes in an array. Although these types of tasks have been used in previous studies [1,22,23], this is the first investigation to make a direct comparison of the two, using a dual task method.

A bar fit task [21-23] will be used to look at the visuospatial use during the change detection tasks, with a verbal parity task [24] being used to show any of verbal material use within the tasks and the use of the phonological loop memory component.

Based upon suggestions made by Brown et al. [19] regarding the visual Patterns Test, it is predicted that the visuospatial secondary will affect the two types of change detection tasks in Experiments 1 and 2.

A second prediction proposes that the verbal secondary task will also have an effect upon both change detections tasks in Experiments 1 and 2, indicating the utilization of a multi-component working memory model.

Methodology

Design

In experiment 1, 19 participants (5 males, 14 females with a mean age of 23 y, SD of 4.48) took part in the quantitative dual task experimental protocols. In experiment 2, 11 participants (all female with a mean age of 21 y, SD of 3.13) took part.

Participants were either Undergraduate students at North Umbria University or were living in Newcastle-upon-Tyne if they were not attending a university at present. Exclusion criteria included if the participant was color-blind or had any photosensitive condition such as photosensitive epilepsy.

Participants

It was a cross sectional descriptive study in 2017. The data was derived from a questionnaire consisting of closed-end and open-ended questions. The questionnaire was developed by the researcher and was checked for validity from external auditors. The validity of the content was 0.72. It was self-administered by questioning the level of opinion in the medical students about the competencies arising from the learning set in the learning outcomes of PBL. The level of opinion was divided into 5 levels as per Likert scale as following; 5 = most agree, 4 = much agree, 3 = fair agree, 2 = less agree, and 1 = least agree.

The questionnaires were sent to medical students who studied in academic year 2012-2015 (2nd to 5th year of medical students) without random sampling. Student names and codes were closed confidentiality in response to the questionnaire.

Measures

Experiment 1: Quantitative primary task: A color change detection task was implemented. Participants were shown a fixation cross for 1000 milliseconds. An encoding image consisting of 4 or 6 colored squares (900 ms) was then shown before a 4000 ms maintenance interval (with interference or a blank baseline measure). Finally, participants were shown a retrieval array, containing one central square, for 3000 ms. Participants had to decide if the color was the same (or not) as any of the squares in the previously shown encoding array in that trial. P was pressed on the keyboard if the colors were the same and Q was pressed if the colors were different. A total score of 20 on each task could be awarded (Figure 1) which shows quantitative primary change detection task.

Experiment 2: Qualitative primary task: This task was a shape change detection task. Participants were shown a fixation cross for 1000 ms. An encoding image consisting of either 1 or 2 shapes (900 ms) was then shown before a 4000 ms maintenance array (with interference or a blank baseline measure). Finally, participants were shown a retrieval array, which used one central shape, for 3000 ms. They then had to decide if the shape was the bigger or smaller than the corresponding shape in the previous encoding array of that trial. P was pressed on the keyboard if the shape was smaller and Q was pressed if the shape was bigger. 24 could be the total score on each task that could be awarded due to the inclusion of 4 types of percentage changes in shape size (5%, 10%, 15% and 20%) (Figure 2) for the qualitative primary change detection task.

Experiments 1 and 2: secondary tasks: Bar fit task: In this task, participants were presented with three images, one after the other. Each image displayed one rectangular bar that was positioned just above two other bars. Participants were asked to note whether the top bar could fit between the lower two bars, pressing keys on the keyboard. P was pressed for a fit and Q was pressed for a no-fit. This task lasted for 4000 ms [21].

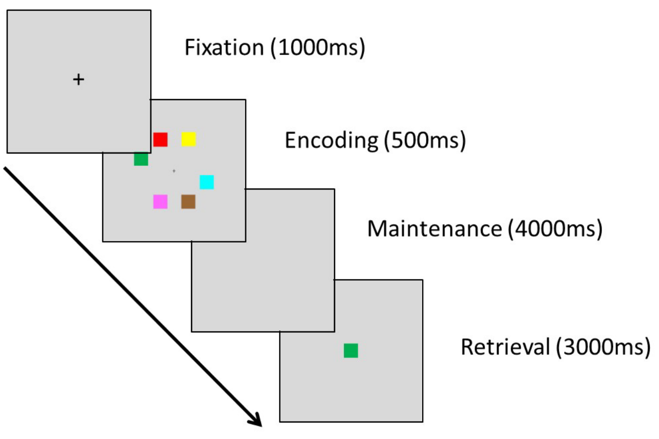

Figure 1: One trial for the quantitative change detection task containing array size 6.

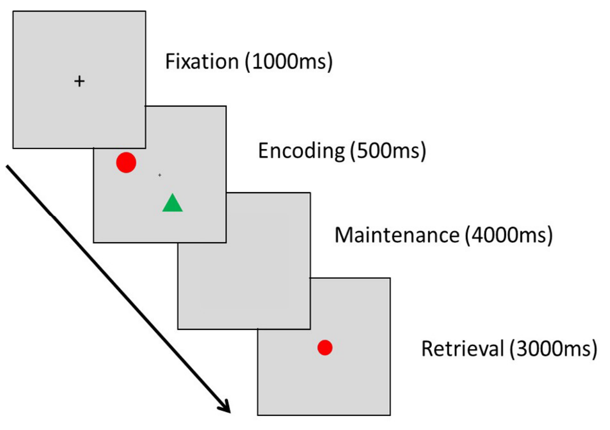

Figure 2: An example of one trial for the qualitative change detection task containing array size 1.

Verbal parity task: participants verbally heard three sequential numbers (any ones between 1 and 9). Participants had to note whether each number was odd or even and responses were given after each number (not the sequence itself). P was pressed for an even number and Q was pressed for odd number. This task lasted for 4000 ms [24].

Procedure

A similar procedure was used for both Experiments 1 and 2, with the only difference being the type of primary change detection task. The experimental procedure was verbally and visually detailed to participants and an information sheet was given before consent was provided.

This procedure consisted of 12 different components, including 3 task information sheets for the two secondary tasks and the chosen primary task, 3 practice tasks, 3 baseline tasks and 4 dual task procedures (2 dual task procedures per array size.). The order of programme presentation was randomly ordered. The session lasted one hour.

Participants completed the experiment and were given the appropriate instructions at the beginning. Once the instruction sheet had been read, a practice task was given. Once all practice tasks had been completed, baseline measures were taken before the six dual task conditions were randomly implemented. Participants were provided with a short rest break between each computerized task.

Results

Raw scores were calculated using a total score of 20 for experiment 1 (quantitative change detection protocol) and a total score of 24 for experiment 2 (qualitative change detection protocol). As dual task procedures were implemented, please see the analyses below which include the dual task amended scores. Raw scores of all conditions can be seen in Table 1, below. Raw scores and baseline measures were used to ensure that participants were not performing at floor or ceiling level.

To take into consideration the use of a dual task cost, Mu scores were calculated. Orme used an adapted formula of Baddeley et al. [14] (Figure 3 and Table 2).

Experiment 1: Quantitat ive change detection task: A 2 × 2 repeated measures ANOVA indicated no significant main effects of set size were found F (1, 10)=1.724, p=0.218 partial η2=0.147, no significant main effect of interference type F (1, 10)=0.110, p=0.747, partial η2=0.011 and no interaction interactions between array size and interference type, F (1, 10)=2.880, p=0.121, partial η2=0.224.

T-tests on quantitative Mu scores: One sample t-tests were conducted to show distinct deviations from the Mu mean of 100. Mu scores for both visuospatial and verbal interferences in array size four were significantly different from 100. Array size 4 visual interference presented an average of 83.23 (SD=14.44), t (10)=-3.849, p=0.003, and the verbal interference presented an average of 87.29 (SD=7.06), t (10)=-5.965, p ≤ 0.001. For array size six, only the verbal interference was significantly lower than 100, presenting an average of 86.86 (SD=5.38), t (10)=-8.085, p<0.001. Table 3 shows the effect seizes associated with these tests, indicating a larger effect with both verbal interferences.

A 2 × 2 repeated measures ANOVA indicated no significant main effects of set size were found F (1, 9)=0.008, p=0.929, partial η2=0.001, and no interaction interactions between array size and interference type, F (1, 9)=1.667, p=0.308, partial η2=0.15. However, a significant main effect of interference type was present. The verbal interference presented a lower Mu score (mean of 90.40, Sd=13.09) than the visuospatial Mu (mean of 103.85, SD=14.20), F (1, 9)=6.259, p=0.034, partial η2=0.410 (Table 4).

T-tests on qualitative Mu scores: Similar to the quantitative protocols, one samples t-test were conducted. Only the verbal interference for array size 1 demonstrated a significant effect of verbal interference, t (9)=-2.804, p=0.021. Table 5 below presents the effect sizes associated with each condition.

Experiment 2: Percentage change analysis-qualitative protocol: For this analysis, researchers re-ordered the raw data, creating two groups of ‘small 5-10% changes and large 15-20% changes. Error rates were calculated with 0 meaning no errors and 1 meaning 100% errors.

A 3-way ANOVA was carried out on each of the visuospatial and verbal interference sets of data (Table 6) for the error rates of the interference conditions.

Variables	Baseline (no interference)	Visuospatial (Bar fit)	Verbal (Verbal parity)
Array size 4 (quantitative)	17.81 (1.53)	14.81 (2.71)	15.09 (2.84)
Array size 6 (quantitative)	14.63 (1.43)	13.63 (3.04)	12.27 (2.76)
Array size 1 (qualitative)	17.7 (3.02)	18.5 (2.99)	15.50 (2.75)
Array size 2 (qualitative)	19.30 (1.15)	19.20 (2.25)	17.10 (3.24)
20 could be scored on the quantitative task and 24 could be scored on the qualitative task due to the arrangement of percentage changes.			

Table 1: Means and standard deviations of the raw scores of the quantitative and qualitative protocols.

$$mu = \left[\frac{\left(\frac{ps-pd}{ps}\right)+\left(\frac{ss-sd}{ss}\right)}{2}\right] \times 100$$

ps = primary task score, single procedure
pd = primary task score, dual procedure
ss = secondary task score, single procedure
sd = secondary task score, dual procedure

Figure 3: Orme's formula for the Mu calculations.

Variables	Visuospatial Mu	Verbal Mu
Array size 4	83.23 (14.44)	87.29 (7.06)
Array size 6	94.04 (22.52)	86.86 (5.38)

Table 2: Means and standard deviations of the quantitative Mu scores calculated using the above formula.

Variables	Visuospatial Mu	Verbal Mu
Array size 4	d=0.852	d=1.600
Array size 6	d=0.193	d=1.694

Table 3: Quantitative (Mu) effect sizes.

Visuospatial (Bar fit) interference: No significant effect of interference was found from the 3-way ANOVA F (1, 9)=0.207, p=0.660, partial η2=0.022, no significant main effects of array size were presented F (1, 9)=2.674, p=0.136, partial η2=0.229 and no interactions were displayed (all p's>0.05). A significant effect was presented for change size, F (1, 9)=30.766, p<0.001, partial η2=0.774 with the error rate being higher for the small 5% and 10% (overall mean=0.257, SD=0.11) compared to the larger 15-20% changes (overall mean=0.129, SD=0.15).

Verbal (Parity) interference: A significant effect of interference was found from the 3-way ANOVA F (1, 9)=9.221, p=0.014, partial η2=0.506, no main effects of array size were found F (1, 9)=4.730, p=0.058, partial η2=0.344. However, a highly significant main effect was associated with change size, F (1, 9)=22.182, p<0.001, partial η2=0.711 where the error rate was lower for the large 15-20% changes than the small 5-10% changes. Of importance, one significant interaction was presented in the data, Interference × Change size, F (1, 9)=6.683, p=0.029, partial η2=0.426.

To provide further analyses of the interaction, paired samples t-tests were conducted on the data. Array size 1 demonstrated no significant differences between the interference types of the small changes, t (9)=-0.705, p=0.499, but there was a significant difference between the interference type of the larger changes, t (9)=-4.788, p=0.001. Higher error rates with the verbal interference drove the interaction.

Similar findings were presented for array size 2 with no significant interference differences presented within the smaller changes, t (9)=-1.424, p=0.118 but verbal interference effects with the larger changes. The verbal interference condition had higher error rates (mean=0.23, SD=0.21) in comparison to the baseline mean (mean=0.07, SD=0.12), t (9)=-2.539, p=0.032.

Discussion

The current investigation aimed to clarify the functional working memory architecture used during a quantitative and qualitative visual change detection protocol. Experiment 1 used a quantitative change detection task and experiment 2 used a qualitative change detection task to compare the architecture. The current research aimed investigate whether a visual only perception, as originally proposed by Luck et al.

Variables	Visuospatial Mu	Verbal Mu
Array size 1	105.80 (19.84)	88.70 (12.41)
Array size 2	101.90 (8.56)	92.10 (13.77)
*Visuospatial=Bar Fit Task, Verbal=Verbal Parity Task		

Table 4: Means and standard deviations of the quantitative Mu scores calculated using the above formula.

Variables	Visuospatial Mu	Verbal Mu
Array size 1	d=-0.330	d=1.129
Array size 2	d=-0.199	d=0.765
*Visuospatial=Bar Fit Task, Verbal=Verbal Parity Task		

Table 5: Qualitative (Mu) interference effect sizes.

Variables	Baseline		Bar fit		Verbal parity	
	Small	Large	Small	Large	Small	Large
Array size 1	0.29 (0.13)	0.13 (0.13)	0.25 (0.12)	0.17 (0.16)	0.35 (0.14)	0.33 (0.01)
Array size 2	0.24 (0.07)	0.07 (0.12)	0.24 (0.10)	0.15 (0.14)	0.31 (0.14)	0.23 (0.21)

Table 6: Means and standard errors of the error rates associated with the interference types.

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[1] or a multi-component perception of working memory could be used to explain the information use during these tasks [4,19,20].

Observations from the review of Luck and Vogel [8] suggested that visual memory tasks must are visual specific, with evidence provided from the research of Shah et al. [17] emphasizing no correlations between visual and verbal span measures. However, research from Brown et al. [18] proposed the presence of verbal strategies use within visual tasks such as the VPT, contradicting the original visual specific suggestion. Results from experiment 1 (quantitative dual task protocols) indicated the use of visual, spatial and verbal material during the change detection task, with effects of the bar fit task and verbal parity task. This provides researchers with initial indications of a less visual-specific task whereby the use of verbal information or semantics may be present, supporting both predictions 1 and 2 of the current investigation. Results of experiment 2 (qualitative change detection protocol) indicate substantial interference effects from the verbal parity task only, with no indication of visual and spatial interference. The qualitative findings suggested from the dual task investigation initially indicate the use of a multi-component approach due to the lack of the visuospatial interference. However, details will be provided regarding the use of small and large types of changes during shape stimuli presentation as this could potentially be a reason for results.

The current findings show support for both [4,19,20], who all suggested the less visual specific nature of visual working memory tasks. The quantitative task, in the current study, may be seen more domain general, indicating that participants may have used could have used elements of visual and semantic processing. The presentation of verbal interferences during the qualitative task also indicates a more multi-component approach to the working memory architecture of this task, opposing the visualization views about qualitative measures. Instead, the visual information use during this task could be supported by some form of verbal strategy use or episodic Buffer component to integrate visual and verbal material. The lack of visuospatial interference effects may be further explained if a more visual specific interference task, such as dynamic visual noise [25-27] was used to eliminate any potential spatial representation use.

Evidence has also been provided of potentially an executive resource use or an episodic buffer component use like that of Logie's [18] multi-component memory model. The use of the phonological loop component alone can be eliminated here as visuospatial interference effects were present, evidenced from the Mu calculations. The use of the phonological loop component would require interference from the verbal parity task only and as this was not the case, a third component must be at use which directs both visuospatial and verbal types of representations through memory. As visual and spatial interferences were presented, the use of a more generalized working memory component can be suggested such as that of the episodic buffer. As the verbal interference influenced both change detection primary tasks, this could indicate the use of multiple representation types, such as those of a visual and verbal nature which could be supported by an episodic buffer component. Unlike the Central Executive component, developed from the model of Baddeley [16], the episodic buffer of Logie's approach shows how the details are passed through memory. Baddeley's central executive controlled the direction of visual and verbal material; however this component ensured the clear distinction of the material types.

The current results do not support that of Vergauwe et al. [21] as interference effects were only presented for array size 4. It could be suggested that array size array size 6 is too large and is therefore too demanding upon visual working memory. Vergauwe et al.'s [21] findings could suggest interference effects with regards to the qualitative change detection task as this is also a visual task; however, results were shown to not be the case. One reason for such discrepancies in results could simply be due to the stimuli differences in Vergauwe et al.'s [21] study and that of the current study. The current study created a version of Luck and Vogel's change detection procedure whereas Vergauwe et al. [21] had used a matrix type task which had been extensively used in previous literature. As this was the first investigation to use the adaptation of Luck et al.'s [1] original paradigm and a newly created qualitative shape change detection protocol, the results provided are novel in terms of stimuli use and can provide researchers with potential further investigations.

The current investigation raises a question with regards to the development of future qualitative change detection protocols which may make use of both small and large changes in shape size. Current results, when running an analysis on the percentage changes, indicated interference effects for the larger changes only which may not be qualitative stimuli. As the 15-20% changes may be questionable as to whether they are qualitative in nature, future investigations should make use of smaller changes only (no larger than 15%). In these cases, interference effects may not be present, which could indicate that high fidelity visual representations only are used during this task, like suggestions made from Hamilton [11].

Although current researchers attempted to make the qualitative and quantitative tasks equal in cognitive ability, it has become apparent that the potential of binding was present in the qualitative task procedures [10,28], making the task presumably more difficult that it's quantitative counterpart. The difficulty of adding two shapes into the qualitative change detection protocol is one which could have increased the task difficulty to a level where the verbal and visuospatial interference effects were not presented within these smaller changes. The use of different colored shapes is also a one which may have taken the focus away from participants looking at size changes only. In future, it may be a preferable idea to only use one shape per encoding array for the qualitative protocols, similar to the square stimuli similar to that of Phillips et al. [11]. Alternatively, eliminating the use of different colors within this task may increase the performance level and ensure that binding effects do not occur. The use of 50% smaller changes and 50% larger changes within this task is also a one that could be addressed. As this task is defined by using smaller changes in visual arrays, a repeat of this investigation may want to consider eliminating the larger 15-20% changes or using a smaller quantitative of such arrays.

The current research did employ a 500 ms encoding time, similar to that of Luck et al. [1]. Luck et al. [1] suggested that this time was used to limit the use of long-term memory and the influence of proactive interference effects [29]. Lin et al. [29] had evidenced that longer encoding times of 1000 ms [30] could cause proactive interference effects therefore the implementation of a shorter encoding time attempted to eliminate any proactive interference effects to alter results. It would be interesting to see if the current visual and verbal secondary task interference effects are still present with longer encoding durations of 1000 ms to compare the differences of shorter and longer encoding times in this case. Although proactive interference effects need to be considered with longer durations, if the interference effects are applicable to all encoding durations then this could provide further data in support of a domain general approach and multi-component approach to visual working memory architecture.

A verbal parity and a visuospatial bar fit task were chosen to run dual task contexts within the current investigation. To look in more detail at the contribution of executive resources, a secondary task with similar protocols to the random tapping task used by Brown et al. [19] could be incorporated into future studies. This would highlight the use of more attentional processes within memory, whether this be visual, verbal or spatial. The verbal parity task may be questionable as this task required participants to use a keyboard press to identify odd and even numbers, essentially adding in spatial elements to this task. To give a clearer indication of verbal specific information use, articulacy suppression could be incorporated. The use of multipole secondary tasks would give a clearer idea of the representation issue within visual working memory.

Conclusion

To conclude, the current research has provided evidence towards a more multi-component approach with interactions from visual and verbal working memory components and this supports previous suggestions made from Baddeley. Future investigations should focus upon the specific use of smaller qualitative changes only and eliminate the use of colour in the qualitative change detection protocol to provide researchers with a more direct measure of qualitative size changes in a visual working memory task. The use of a visual specific interference task, such as the DVN, would also be able to identify the use of visual specific working memory components as this research has not done.

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