Distraction of mental arithmetic by background speech: Further evidence for the habitual-response priming view of auditory distraction

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Abstract

When solving mental arithmetic problems, one can easily be distracted by someone speaking in the background and this distraction is greater if the speech comprises numbers. We explored the basis of this disruption by asking participants to solve mental addition problems (e.g. “45 + 17 = ?”) in three different conditions: background speech comprising numbers in ascending order (e.g. “61, 62, 63, 64, 65”), background speech comprising numbers in descending order (e.g. “65, 64, 63, 62, 61”), and quiet. Performance was best in quiet, worse in the descending numbers condition, and poorest in the ascending numbers condition. In view of these findings, we suggest that disruption arises as a by-product of preventing the primed, but inaccurate, candidate responses from assuming the control of action. Alternative explanations are also discussed.

Key words: Mental arithmetic, Irrelevant sound, Habitual responses, Priming

Introduction

In today's work environment, with its increase in technology and information communication, background sound is almost ubiquitous and is a cause of decreased performance on tasks such as short-term recall, mental arithmetic, train timetable analysis, reading comprehension, and the Blocks World (Banbury & Berry, 1998; Jones, 1999; Perham & Banbury, 2012, Perham, Banbury, & Jones, 2005; Perham & Currie, 2014; Perham, Hodgetts, & Banbury, 2013; Perham & Macpherson, 2012; Waldron, Patrick, Morgan, & King, 2007). A simple laboratory demonstration of this situation known as the irrelevant sound effect (ISE) reveals that irrelevant sound can cause a drop in performance of 30-50%, the magnitude of the effect is not affected by preference for the sound (Perham & Sykora, 2012; Perham & Vizard, 2010) and very few people (around 8%) are invulnerable to the distraction (Jones, 1999). In this paper, we explore the novel view that background sound disrupts mental arithmetic performance to the extent that it primes habitual responses that threaten to assume control over behavioral output (Marsh, Sörqvist, Halin, Nöstl, & Jones, 2013).

Mechanisms of auditory distraction

Auditory distraction in the context of the laboratory is best exemplified by the ISE, in which serial recall of a series of 7-9 items, in presentation order, is poorer in a background sound condition compared to quiet. Over the last 40 years or so, a number of theories have attempted to explain this simple, yet robust, phenomenon. These views have been termed “attentional capture” (Hughes, Vachon, & Jones, 2005), “interference-by-content” and “interference-by-process” (Hughes, Vachon, Hurlstone, Marsh, Macken, & Jones, 2011). One example of the interference-by-content approach is the notion that the ISE is a function of the overlap in the phonemes of items in the background sound and the to-be-recalled visual items (Salamé & Baddeley, 1982). Interference-by-content views, however, experience difficulties explaining why, for example, non-phonological sounds such as tones, office noise and instrumental music also impair short-term serial recall performance (Jones & Macken, 1993; Perham, Banbury, & Jones, 2007a; Tremblay, Macken, & Jones, 2001). The attentional capture view assumes that sound captures attention away from the focal task, thereby reducing the level of attentional resources available for any demanding focal task (Bell, Röer, Dentale, & Buchner, 2012; Cowan, 1995). This attentional capture view is consistent with the observation that people habituate to the disruptive effects of background sound (Bell et al., 2012; Röer, Bell, & Buchner, 2014a, 2014b). Typically, however, some degree of distraction is still present after habituation (Röer et al., 2014a; Tremblay & Jones, 1998) suggesting that other mechanisms contribute to distraction as well. One candidate mechanism is interference-by-process whereby the ISE is a joint function of the acoustical variability of the sound and the degree to which effective performance on the focal task requires serial rehearsal. For instance, the changing-state effect is when a changing-state sound sequence ("n, r, p…") produces more disruption than a steady-state sound sequence ("c, c, c…"), at least when task performance necessitates rehearsal of the to-be-recalled items in their order of presentation (Beaman & Jones, 1997, 1998; Marsh, Hughes, & Jones, 2009; Perham, Banbury, & Jones, 2007b). It is possible to experimentally disentangle the attention capture and the interference-by-process mechanisms (Hughes, Vachon, & Jones, 2005, 2007). For example, task-instruction manipulations show that deviant sound—which captures attention—disrupts serial recall of a list of items as well as the ability to identify a missing item from a list of items, while changing-state sound sequences without abrupt deviants only produce disruption to serial recall but not to the missing item task (Beaman & jones, 1997; Hughes et al., 2007). Moreover, making the to-be-recalled items harder to perceive at encoding blocks attention capture but does not increase resistance to the changing-state effect (Hughes et al., 2014). In view of these findings, a duplex-mechanism account has been developed (Hughes, 2014) which suggests that auditory distraction is a joint product of attention capture and interference between processes.

Also consistent with the duplex-mechanism account are the findings concerning how semantic properties of the background sound contribute to disruption of serial recall. On the one hand, the magnitude of the irrelevant sound effect is comparable regardless of whether participants can understand the background sound (Colle & Welsh, 1976; Jones, Miles, & Page, 1990) or whether the content of the sound is semantically similar to the to-be-recalled items (Buchner, Irmen, & Erdfelder, 1996; Marsh, et al., 2009, but see Hughes & Jones, 2005). For example, Buchner et al. (1996) found that serial recall of lists of two-digit numbers was no more disrupted by to-be-ignored two-digit numbers (that were not part of the to-be-recalled list) than it was by non-words that comprised the phonemes of the numbers, or word combinations whereby the phonemes of the irrelevant items were similar to those of the to-be-recalled numbers. Moreover, this same study showed that the “semantic distance” between the to-be-recalled and to-be-ignored items also played no role in the degree of interference: Irrelevant items that were within the same decade as the to-be-recalled numbers but 2 or 5 above or below, produced as much disruption as those drawn from 2 to 5 decades above or below the to-be-recalled numbers. The absence of disruptive effects related to the meaning of the sound in the serial recall task is likely to be a consequence of the fact that, typically, the to-be-recalled information is a relatively short list of homogenous and relatively semantically-impoverished verbal items (e.g. digits; Beaman & Jones, 1997; Buchner et al., 1996). Due to the lack of semantic-based strategies in the serial recall task, in this context there is no conflict between the task-related processes and the obligatory semantic processing of the background speech. These findings speak for an interference-by-process mechanism underpinning distraction. On the other hand, when the background sound comprises items with high valence (Buchner, Mehl, Rothermund, & Wentura, 2006; Buchner, Rothermund, Wentura, & Mehl, 2004) or self-relevant items such as the listener's own name (Röer, Bell, & Buchner, 2013), disruption to serial recall increases. These findings are more consistent with an attention capture mechanism whereby disruption is produced by the sound diverting attention away from the memoranda.

The interference-by-process explanation receives further support from the finding that the effects of the semantic similarity, between words within a to-be-ignored background sound and words to-be-recalled (e.g. when all words belong to the same semantic category), is modulated by the task instructions. The effects of the semantic similarity are larger when the task is to recall the items in free order, in comparison with when the task requirement is to recall the items in order of presentation (Marsh, Hughes, & Jones, 2008, 2009; for an analogous finding in relation to phonological similarity, see Marsh, Vachon, & Jones, 2008). This between-sequence semantic similarity effect manifests as impaired veridical recall of the to-be-recalled items and as an increase in erroneous recall whereby, typically, the to-be-ignored items intrude into the recall protocol (Marsh, Hughes, Sörqvist, Beaman, & Jones, 2015). Of particular interest to the present study, erroneous recall (of the to-be-ignored words) is greater when the words that comprise the background speech are high in output dominance (e.g. the word DOG from the category four-legged animals) in comparison with then they are low output dominant (e.g. the word BADGER from the category four-legged animals; Marsh, Sörqvist, Hodgetts, Beaman, & Jones, 2014). One interpretation of this finding is that to-be-ignored high output dominant category exemplars—that are arguably habitual responses—more easily come to mind at recall, especially when primed by the background speech, and thus have to be inhibited so as not to intrude covertly, or overtly into the recall protocol (Marsh, Beaman, Hughes, & Jones, 2012; Marsh et al., 2014). In this context, the distracter items appear to compete for action (i.e., recall output). A similar example of this disruption produced by irrelevant semantic material competing for action has been observed in the context of the Stroop effect. To read the printed word is a habitual response, but the response is inappropriate in the context of naming the color in which the color-word is presented, and produces interference by competing for verbal output (Elliott, Cowan, & Valle-Inclan, 1998). Deterioration in focal task performance [reduced veridical recall (Marsh et al., 2015) or slowed color-naming (Elliott et al., 1998)] may arise as a side effect of the executive mechanisms that prevent irrelevant responses from commandeering the control of action. From here on, the term “competition-by-action” is used as replacement of “interference-by-process” because it specifies the underpinning mechanism in greater detail.

That background sound produces substantial distraction when it contains information that primes habitual responses in the context of the focal task has recently been shown in the context of the random number generation task (Marsh et al., 2013). Here, the participants’ task was to generate a sequence of single-digit numbers in a random fashion, thus avoiding habitual-response sequencing such as the production of the sequence “1 2 3 4” and “2 4 6 8”. The randomness of the generated sequence was compromised when background sound comprised numbers in canonical order (“1 2 3 4 5 6 7 8 9”) whilst it was unaffected by background sound that comprised of numbers in random order. Similarly, Buchner, Steffens, Irmen, and Wender (1998) found that distracters that formed an ascending pattern (e.g. “6, 7, 8”) produced slightly more disruption to counting than distracters that formed no pattern, but only when numbers were close to the running total within the task. Both findings suggest that background sounds that prime contextually-relevant, but response-inappropriate information for the focal task (such as overlearned sequences of responses) impair performance. One possibility as to why this is the case is that highly primed responses compete for the control of action, or in other words threaten to seize the control of output. Therefore, these primed responses must be inhibited so that the task requirements can be fulfilled. However, such inhibition of the irrelevant carries a cost to performance, either because inhibition is incomplete or because the deliberate act of inhibition comes with an overhead cost to performance (Marsh et al., 2012, 2014). In the current paper, we seek further evidence for the generalizability of this novel finding to mental arithmetic—a task arguably more common in applied settings.

Distraction of mental arithmetic

Research suggests that mental arithmetic may be impaired by background sound in a similar way to short-term memory. For example, both speech and non-speech sound disrupt a running total mental arithmetic task (e.g. 7+5+9+3+2+4 = ?; Banbury & Berry, 1998; Hadlington, Bridges, & Beaman, 2006; Perham, Hodgetts, & Banbury, 2013). That background sound comprising office noise with speech produces more distraction than office noise without speech in both serial recall and mental arithmetic tasks (Perham et al., 2013) suggests that the magnitude of disruption of mental arithmetic by sound is modulated by the degree of acoustic change within the sound. This is consistent with the idea that some forms of mental arithmetic require serial processing. For example, one way in which mental arithmetic problems are solved is through procedural processes involving counting whereby the individual reaches the solution by ascending or descending the numerical scale one by one (Imbo & Vandierendonck, 2007) and transformation whereby individuals use related operations and known facts. For example, computation of the solution to “26 + 7” may entail transforming the problem to “26 + 4 + 3” (through recognition that 7 is the same as 4 + 3) and then adding 4 to 26 to make the known fact “30” then adding the remaining 3 to make the correct total of “33”. Mental arithmetic problems, such as these that involve subvocal verbalization to keep track of running totals, ascend or descend numerical scales, or temporarily store immediate or partial results when required, should be much more susceptible to disruption via the changing-state properties of speech than mental arithmetic problems that can be solved through direct retrieval from long-term memory such as retrieving the answer “9” when given the mental arithmetic problem “6 + 3.”

Unlike short-term serial recall, however, superimposed on this changing-state effect in the context of the mental arithmetic task, is a between-sequence semantic similarity effect. For example, Perham and MacPherson (2012) found that background sound comprising auditory numbers similar to the to-be-calculated number (e.g. 29, 30, 31, 32, and 33 if the solution was 28), compared to dissimilar to the to-be-calculated number (e.g. 72, 73, 74, 75, and 76 if the correct answer was 28) produced greater impairment. This is consistent with the competition-for-action account since unlike serial recall, wherein semantic processing of the task material is rather inconsequential for effective task performance, the semantic processing of the task-relevant digits determines effective task performance. Therefore, a competition between the semantic processing of digits should occur, especially when the speech activates habitual response patterns that the individual also uses for the mental arithmetic task (such as ascending the numerical scale). Furthermore, prior findings within the context of mental arithmetic assume that arithmetic facts are retrieved from a network of associative links whereby candidate items become activated and the participant must select the appropriate response from among these competing alternatives (LeFevre, Bisanz, & Mrkonjic, 1988). From the response priming view, selection of the solution would be made much more difficult if the background sound primes an incorrect, but semantically similar item (e.g. “57” as opposed to “27” when the solution is “58”; see Perham & MacPherson, 2012) since significant control over action must already be exerted to prevent the selection of the erroneous candidates, and priming incorrect solutions will require more by way of cognitive control to prevent them from assuming behavioral output (Marsh et al., 2012, 2013, 2014). Although the semantic distance effect within the context of auditory distraction and mental arithmetic is now established, it was done so by using background speech comprising *ascending* sequences of numbers (Perham & MacPherson, 2012). The response priming view suggests that an ascending sequence will produce impairment because it embodies a sequence that is already in competition for the control of action: participants count upwards in ones to reach the solution. Stronger support for the response-priming view would be obtained if an ascending sequence of numbers (e.g. “23, 24, 25, 26, 27”) produced more distraction than a descending sequence of numbers (e.g. “27, 26, 25, 24, 23”) when both were globally equidistant to the solution (e.g. “28”).

In the current study, we further tested the habitual response-priming hypothesis—embedded within the competition-for-action account of distraction (e.g. Marsh et al., 2013)—by asking participants to perform addition mental arithmetic problems (wherein the numerical scale is ascended) in the presence of three sound conditions: Ascending numbers, descending numbers and a quiet control condition. Support for the response-priming view would be obtained if mental arithmetic performance is impaired more by background sound comprised of numbers in ascending order, because the sound would—on this view—threaten to seize control of the processes required for adding lower numbers into higher numbers. As a counterpoint, the interference-by-content view (e.g. Salamé & Baddeley, 1982) predicts performance impairments in both sound conditions, because there is an overlap between the items in the background sound and the to-be-calculated numbers. However, according to the interference-by-content view, there should be no difference between the two sound conditions because this view makes no assumption about the compatibility between the processes engaged in the task and the involuntary analysis of background sound.

Method

Participants

Thirty-three undergraduate students from a university in the south of Wales participated in exchange for course credit. All participants had normal hearing and vision, were between 18 and 30 years of age.

Materials

Mental arithmetic problems. *PowerPoint* was employed to present each participant with twenty different mental arithmetic addition problems for each of the three conditions. Each problem was constructed using numbers ranging between 11 and 79, with the answers from numbers between 23 and 99. Any problems using tie operators (e.g. 16+16) or numbers ending in a 0 or 5 were considered too easy to calculate and thus not used in this experiment (Lefevre et al., 1988). Each of the addition problems used was considered as hard, by ensuring the answer exceeded the tens boundary: for example 17+36 (Imbo & Vandierendonck, 2007; Perham & Macpherson, 2012). This was to maximize the chance that the problems were solved using non-retrieval strategies such as rehearsal. The smallest number in each problem was presented first and each problem was on the screen for three seconds. Following their presentation, a blank slide appeared for two seconds to allow participants to write down their answer on a response form.

Sound. The irrelevant sounds were recorded using the software program *Multi-Speech*. Each sound consisted of either five numbers or words, with each number or word being presented for approximately 700ms followed by approximately 300ms of silence and began as soon as the problem was presented. The ascending condition had the numbers increasing immediately after the solution to the problem. For example if the problem solution was “53” then the similar ascending numbers were “54, 55, 56, 57, 58”. The descending condition had the irrelevant numbers decreasing from the number immediately below the solution to the problem. For example, if the problem solution was “26” then the similar descending numbers were “25, 24, 23, 22, 21”.

Design and procedure

A repeated measures design was adopted with the within-subjects variable being sound. It had three levels: quiet, ascending numbers and descending numbers. The order of presentation of the sounds was counterbalanced so that each sound was placed in each position an equal number of times. The dependent variable was the number of mental arithmetic problems answered correctly.

Participants were tested in small groups of one to five in a computer room under laboratory conditions in order to alleviate any extraneous sounds. They were given standardized instructions asking them to attempt to complete as many of the addition problems possible within the three second time limit before being confronted with the next problem on screen and to ignore any sounds that they heard through the headphones. Participants received two practice control trials, before commencing the actual experiment, in order to prepare them for the experimental structure.

Results

As can be seen in Figure 1, mental addition was best in quiet, somewhat impaired by background speech comprising numbers in descending order, and more impaired by background speech comprised of numbers in ascending order. A repeated measures analysis of variance revealed an effect of condition, $F(2, 64) = 11.88$, $MSE = 0.017$, $p < .001$, $\eta_p^2 = .27$. The descending numbers condition was different from quiet, $t(32) = 2.10$, $p = .043$, and from the ascending numbers condition, $t(32) = 3.54$, $p = .001$. Moreover, the ascending numbers condition was also different from quiet, $t(32) = 3.91$, $p < .001$. With corrections for multiple comparisons following the procedure suggested by Holm (1979), the null-hypothesis for the difference between ascending numbers and quiet would be rejected, as well as the null-hypothesis for the difference between ascending numbers and descending numbers and the null-hypothesis for the difference between descending numbers and quiet.

Discussion

The ability to solve mental addition problems was more impaired by background sound comprised of numbers in ascending order, in comparison with background sound comprised of numbers in descending order. This novel finding supports the competition-for-action account of distraction and in particular the response-priming view (Marsh et al., 2013) whereby task-irrelevant auditory distracters prime responses that threaten to assume the control of output, but only when the primed responses are potential candidates for output. In the context of mental addition, the task is to seek a sum of two numbers that is larger than the two individual numbers; the calculation involves counting by ascending the numerical scale (Imbo & Vandierendonck, 2007), a process that is in conflict with the involuntary extraction of sequential information within the to-be-ignored number sequence when that irrelevant sequence comprises numbers in ascending order that are semantically close to the solution (see also Buchner et al., 1996; Marsh et al., 2013).

Implications for theories of auditory distraction

The observation of a between-sequence semantic similarity effect found in a previous study on mental arithmetic (Perham & Macpherson, 2012)—poorer mental arithmetic performance when the irrelevant numbers are semantically similar to the solution of the arithmetic problems than when they were dissimilar—at first glance would appear compatible with both the interference-by-content and the competition-for-action accounts of auditory distraction. A crucial characteristic of the interference-by-content account is that impairment occurs when the task and the sound contain similar items (e.g. numbers for mental arithmetic). Interference-by-content could occur, for example, when the sound activates representations within an associative network of links and becomes represented with the to-be-calculated solution within working memory. Recall is impaired as a result of the similarity in identity (i.e. content) between the to-be-ignored and to-be-remembered items within the same representational space (Marsh et al., 2009). Note that this account is very different from the competition-for-action view that supposes that preventing retrieval of distracter items, while retrieving the contextually-appropriate or desired response (the solution to the arithmetic equation) carries an overhead cost resulting in impoverished task performance (Marsh et al., 2008, 2012). In this way, the interference-by-content account would appear to receive some support from the difference in performance between the quiet condition and the descending numbers condition of the present experiment.

However, the interference-by-content account cannot explain why the ascending numbers condition produces poorer performance than the descending numbers condition, since the content of the two streams is identical. Moreover, the interference-by-content account offers no explanation as to why non-speech sound (office noise comprising mobile telephone ringing, photocopying, computer humming, typing, printing, telephone ringing, papers being shuffled, doors opening and closing, footsteps and knocking at the door; Perham et al., 2013) significantly impairs mental arithmetic performance, since in this situation there is no overlap in content between the background sound and the mental arithmetic task.

The finding of a difference between ascending and descending numbers condition is more consistent with the attentional capture account (Bell et al., 2012; Cowan, 1995; Röer, Bell, Dentale, & Buchner, 2011) than with the interference-by-content account on the assumption that ascending numbers may be regarded as more task-relevant and more familiar than descending sequences whereby the attentional system is selectively more responsive to this input. The current experiment is inconclusive as to whether the competition-by-action or the attention capture account is the better explanation. However, while sequences of ascending single-digit numbers (such as “5, 6, 7, 8”) may be more frequently encountered than sequences of descending single-digit numbers (“8, 7, 6, 5”) and therefore be more captivating, the current experiment involved the presentation of sequences of two-digit numbers (“55, 56, 57,58”), not single-digit numbers. Assuming that ascending sequences of two-digit numbers are no more familiar than descending sequences, the results appear to be more supportive of a competition-for-action account than an attention capture account. Moreover, one driving mechanism behind attention capture is expectation violation (Röer, Bell, & Buchner, 2014c). The attentional system develops a neural model of past experience with the sound environment upon which it forms expectations of future sound stimulation. When these expectations are violated, the locus-of-attention is switched towards the sound (Hughes et al., 2011). A violation that could precipitate attention capture would be the presentation of the two-digit number “57” in the sequence “53, 54, 55, 57” (cf. Marsh, Röer, Bell, & Buchner, 2013). However, neither the ascending sequences nor the descending sequences in the experiment reported here contained such violations. Because of this, the attention capture account would suppose that both sound conditions should impair performance to the same degree. Taken together, the results appear to be easier to reconcile with the competition-for-action account than the interference-by-content account and the attention capture account.

The competition-for-action view (Hughes et al., 2011) explains the distraction produced by non-speech, speech and speech number sounds neatly. The obligatory processing of acoustic changes within the non-speech and speech sounds disrupt mental arithmetic because it yields serial order information that competes with the deliberate serial motor planning involved in the mental arithmetic task (e.g. using subvocalization to count, keep track of running totals, and store intermediate solutions; Hughes et al., 2005). Moreover, superimposed on this generic irrelevant sound effect are semantic competitions-for-action. One example of these is when background speech primes/activates candidate solutions to the arithmetic problems that are contextually-appropriate (e.g. within the same number range of the solution) but response-inappropriate (e.g. “57” as opposed to “27” when the solution is

"58"). Here, cognitive control must operate to exclude the distracter item from the response (Perham & MacPherson, 2012). The additional disruption produced by the ascending number conditions is due to the activation of a habitual response-sequence—presented by the irrelevant sound—that conflicts with the similar counting process that underpins the mental arithmetic addition task. In general the upwards, as compared to downwards, counting within the background speech superficially fits the task-requirement of ascending the numerical scale to reach the mental arithmetic problem solution. This upward counting schema must be prevented from assuming the control of action, the cost being to increase error in counting on the mental arithmetic task (see also: Buchner et al., 2008; Marsh et al., 2013).

Future directions

The habitual-response priming view yields as yet untested predictions. For example, it would be expected that a descending, rather than ascending, sequence of irrelevant numbers would produce greater impairment if the mental arithmetic involved counting downwards to reach a solution. This is because the descending number speech would prime responses compatible with the attempt to find numbers that are lower than the current running total. At first glance a simple test of this prediction would be to use subtraction as opposed to addition mental arithmetic. However, problematic for this notion is that procedural processes involved in subtraction often involve the process of addition (Campbell, 2008; Torbeyns, DeSmedt, Peters, Ghesquière, & Verschaffel, 2011). For example, although an individual may be taught that "62 + 23 = 85" and that "85 - 62 = 23", one can also solve a mental subtraction problem ("46 – 9 = ?") by seeking the distance between the lower number ("9") and the higher number ("46") through mental addition ("9 + ? = 46"). Therefore any future study addressing the hypothesis would either have to train individuals to solve subtraction problems via addition, or screen participants as to how they perform subtraction. More broadly, the competition-for-action view suggests that the effects of non-speech sounds, and speech sounds that are semantically-dissimilar to the to-be-calculated total, will principally disrupt performance on mental arithmetic tasks that require subvocalization such as calculation processes including transforming, counting, temporary maintenance of intermediate solutions, and keeping track of running totals. Mental arithmetic problems that can be solved through direct retrieval from long-term memory, thereby bypassing subvocalization, should be relatively invulnerable to distraction by non-speech and semantically-dissimilar sounds. However, performance on direct retrieval problems may be disrupted by the semantic distance between a to-be-calculated solution and the numbers within the background sound, as the sound primes competing responses within a network of associative links (LeFevre et al., 1988).

Individual differences may also play a role in impairment here. For example, high working memory capacity is known to modulate impairment from irrelevant sound (Sörqvist, Halin, & Hygge, 2010), at least when attention capture underpins disruption (Sörqvist, Marsh, & Nöstl, 2013) and when semantically-based competition-for-action underpins disruption (Marsh et al., 2014). Working memory capacity appears to be unrelated to the magnitude of the ISE (Sörqvist et al., 2013), but generally high-capacity individuals are less susceptible to distraction than their low-capacity counterparts. Further, dyslexics, and those with difficulties in literacy, have problems with exploiting the long-term knowledge of sequential information and utilise spatial strategies more than non-dyslexics (Bacon, Handley, & MacDonald, 2007; Perham & Howell, 2015; Perham, Whelpley, & Hodgetts, 2012). This suggests that any disruption involving processing order information from long-term memory may be less susceptible to disruption from background sound and further, that individuals who have difficulties processing this order information may adopt additional strategies that could involve other processes such as those involving spatial rotation.

Conclusions

In sum, the experiment reported here provides evidence for the novel view that distraction is most pronounced in settings where the task-irrelevant material is context-appropriate but yet incongruent with the response required for effective task performance. A specific instantiation of this is observed when auditory distracters prime procedures/responses (e.g. counting upward in ones) that are compatible—but ultimately incongruent—with the output required for effective task performance. This response-priming hypothesis is embedded within the competition-for-action view of distraction and functions as a way to specify the nature of the processes responsible for disruption. Future research is required to determine whether also attention capture underpins distraction as reported here, perhaps in collaboration with a competition-for-action mechanism. Future research should also explore whether congruency effects (e.g. greater impairment by descending, as compared with ascending, number speech on subtraction problems) can be found in the context of different versions of the mental arithmetic task. The current study represents an important first step into unravelling the underpinnings of auditory distraction in relation to mental arithmetic performance.

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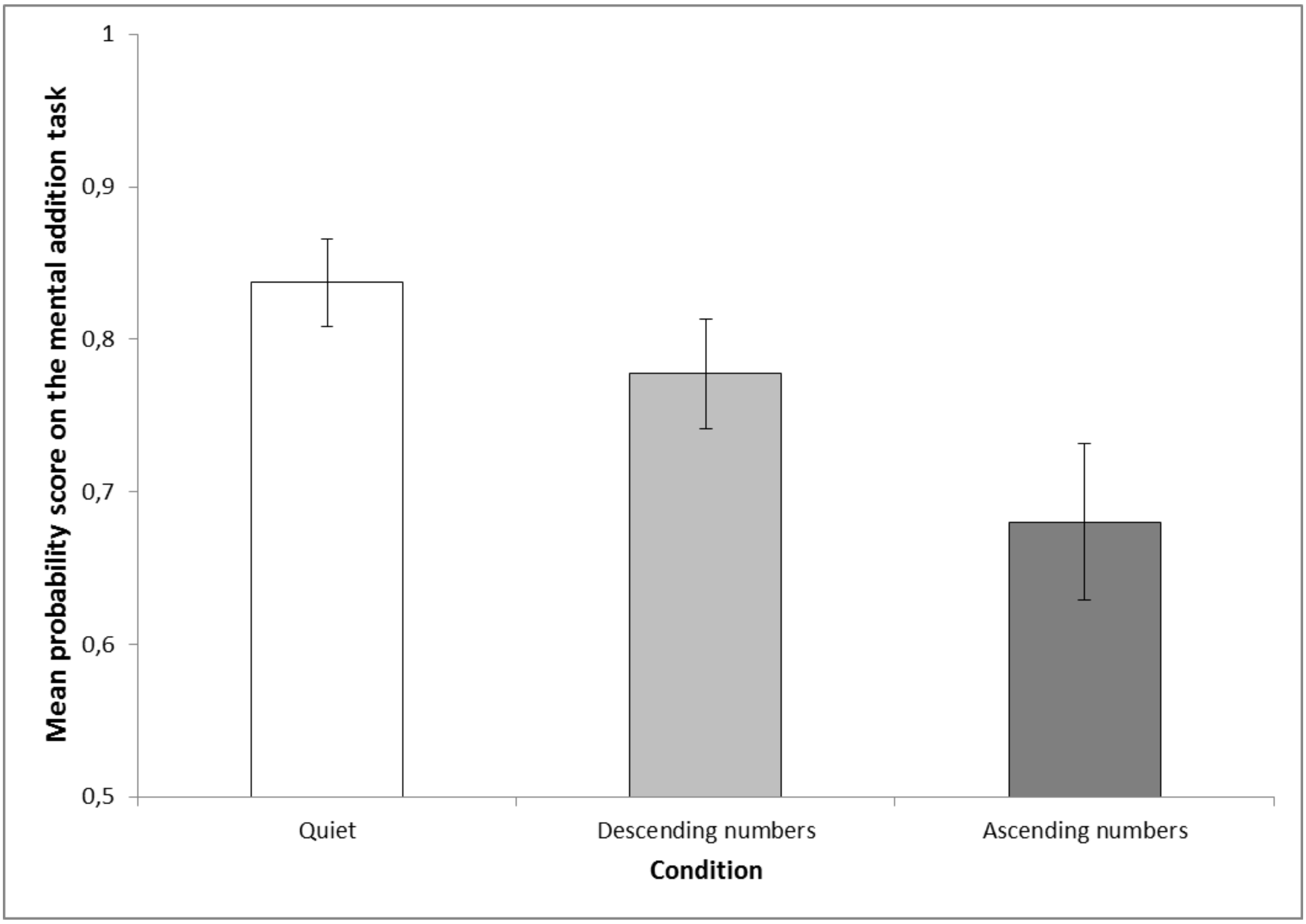
Figure caption

Figure 1. Mean probability score on the mental addition task in three conditions: A quiet control condition, a condition with background speech comprised of descending numbers (e.g., “36 35 34 33 32 31”) and a condition with background speech comprised of ascending numbers (e.g., “41 42 43 44 45 46”). Error bars represent standard error of means.

Figure 1


Mean probability score on the mental addition task
1
0,9
0,8
0,7
0,6
0,5
Quiet
Descending numbers
Ascending numbers
Condition

Acknowledgment

The first two authors contributed equally to the work carried out here.