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EDITORIAL

Emerging perspectives on distraction and task interruptions: metacognition, cognitive control, and facilitation-Part 2

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The constant connectivity provided by tools and technology within the digital world creates an environment wherein interruptions are frequent and selective attention systems are increasingly important to maintain focus on specific tasks amidst a myriad of potential distractions (Dontre, 2020; Roda, 2010). Notifications from emails, social media, instant messaging and an array of apps offer continuous competition for attentional processing. Whilst some modern technology allows us to schedule or disable such notifications via deployment of do-not-disturb or silent modes, others do not have this feature and the sheer volume of different digital communication channels across multiple sensory modalities (e.g. visual, auditory and tactile) makes interruptions, task switching, and distractions prevalent in daily lives (Marsh & Rajaram, 2019).

Whilst task interruption, task switching, and distraction typically lead to similar behavioural outcomes—namely the impairment of focal task performance—they involve distinct processes and thereby have different implications in the context of attention and task performance (Couffe & Michael, 2017). Task interruptions refer to a break in current activity that is caused by an external factor (e.g. a stimulus) that demands immediate attention—such as deliberately attending and responding to an auditory or visual alarm—which brings focal task processing to a temporary halt. Interruptions can incur a cost in terms of time to recommence processing on the focal task (frequently referred to as a resumption lag); they may disrupt place keeping in procedural tasks resulting in omissions, repetitions, or other sequential errors; or they may result in primary task goals being forgotten and not resumed at all (Dodhia & Dismukes, 2009). Task switching refers to the deliberate change from stopping performance on one task to starting performance on another. In contrast to task interruption, task switching is often planned and controlled and involves multitasking whereby an individual alternates between different tasks (e.g. checking emails while writing a report), perhaps through allocating specific times to both activities and/or processes. Frequently switching between two tasks such as classifying a digit member of a digit-letter pair as even or odd or the letter member as a consonant or vowel (e.g. Rogers & Monsell, 1995) typically leads to more error-prone or slower performance (a switch-cost; for a review, see Skaugset et al., 2016). Whilst some might argue that task switches—since they can generally be anticipated and managed by the individual—should be less disruptive than task interruptions, others suggest that self-initiated switches are more disruptive than external interruptions (Katidioti et al., 2016).

Unlike task interruption and task switching, a distraction can either divert attention away from the task at hand, or its processing can interfere with contemporaneous processing of a focal task (Hughes, 2014). Distraction can be external (e.g. continuous background music), or internal (e.g. task-irrelevant thoughts through mind-wandering; Rummel et al., 2024) and, unlike task interruption, are passively as compared to actively processed. Depending on the theoretical perspective adopted, distractors may capture attention away from an active focal task (Bell et al., 2022; Röer et al., 2015), or their preattentive processing may interfere with similar, deliberate processes underpinning mnemonic retention (Hughes, 2014; Marsh et al., 2009). On this latter perspective distractions via, for example, continuous background sound are ongoing which contrasts with task interruptions which are typically short-lived despite producing similarly immediate disruption. Additionally, distractions, unlike task interruptions, do not require immediate attention and action. Whilst distractions can be internal (e.g. mind-wandering) and external (e.g. background telephone conversation), task interruptions are usually triggered by external events that demand attention, such as responding to an auditory alarm or answering a task-irrelevant question. The impact of some forms of distraction can be attenuated over time through habituation of the orienting response to a distractor (Sörqvist et al., 2012) but an analogous amelioration of disruption (i.e. habituation) cannot be achieved in the same way in the context of task interruption where a response is required for the interrupting task.

It is important to consider that not all individuals are equally susceptible to the influence of task interruption, task switching and distraction. In a digital world characterised by a constant influx of information it is important to understand how individual differences in selective attention put some individuals at a disadvantage and some at an advantage in environments that are increasingly filled with distractions, interruptions and the requirements to frequently switch attention between activities. Investigating individual differences in selective attention is important for several reasons. For example, it can inform the design of technology and user interfaces. Devices and applications can be developed to minimise distraction and better management of focal attention for diverse user groups. Further, analyses of different selective attention processes can lead to personalised strategies, or training programmes based on individual needs to resist disruption from distractors, and thus improve attentional focus. In the workplace productivity might be improved by the allocation of employees to roles and situations that match their selective attentional strengths or optimising work environments (reducing sources of distraction). For example, in the context of safety critical activities such as Air Traffic control and surveillance, defence and security organisations may want to screen individuals for those with high attentional control and cognitive flexibility (cf. Marois et al., 2021). Investigating neural mechanisms underlying selective attention can contribute to the development of new interventions for attentional deficits. Further, selective attention is also closely linked to mental health and thus investigating individual differences in this domain can provide a window onto how attentional issues contribute to disorders such as attention deficit hyperactivity disorder (ADHD), anxiety and depression and differ between neurotypical and neurodiverse groups. Such insights might improve diagnosis and treatment plans.

Emerging perspectives on distraction and task interruptions, Part 2: insights from task interruption, task switching and neurodivergent populations

In Part 2 of this three-part Special Issue (for part I, see Marsh et al., 2024), we present eight articles that shed light on theories of task interruption, task switching and individual differences in susceptibility to auditory, visual, and tactile distraction in neurotypical and neurodivergent populations.

Task Interruption and Task Switching

The articles within this subtheme (Altmann & Hambrick, 2024; Piątkowski et al., 2024; Sio et al., 2024) have several commonalities. For example, Altmann & Hambrick (2024) and Piątkowski et al. (2024) investigate how participants adapt their strategies, and use compensatory mechanisms, in response to task interruptions using internal (mnemonic aids) and external (reminder function) cues (Altmann & Hambrick, 2024), or the similarity in processing between the focal and interrupting task (Piątkowski et al., 2024). The influence of overlap in task processing is also investigated by Sio et al. (2024) whereby similarity between problem-solving tasks may lead to compensatory strategies (e.g. broader search scope). Labonté et al's (2024) focus on how forewarned interruptions affect complex task performance over longer periods, rather than just immediately following an interruption, and the finding of poor metacognitive awareness of disruption produced by task interruption preceded by a forewarning, provides a holistic perspective that aids understanding of the full impact of task interruptions.

In overview, Altmann & Hambrick (2024) used an interrupted task paradigm to examine participants' adaptive strategies under different task constraints. Using a procedural task comprising a series of two-choice decisions, participants were given either a mnemonic or not (UNRAVEL vs UNRBCEL) to remember the sequence order of seven steps in the face of frequent interruptions (Exp 1). Performance did not differ between the two groups, with those in the non-mnemonic condition compensating for the lack of mnemonic support by making greater use of a reminder function. In Experiment 2, all participants were given the UNRAVEL mnemonic but for one group, the use of the help function was limited. Again, errors did not differ between groups suggesting a compensatory strategy with those having limited available help adapting to the lack of environmental support with more memory intensive strategies. Together the experiments indicate an implicit performance optimum on the task, and that participants can compensate to achieve this optimum by drawing upon an external or internal resource.

Piątkowski et al. (2024) examined whether goal forgetting during interruptions in a procedural task (an adapted version of UNRAVEL) is moderated by the similarity between the interrupting and interrupted tasks. Experiment 1 found that errors following interruption (a letter processing task) were fewer when there was overlap between the letter denoting the subtask just achieved in the primary sequence, and that used in the secondary task, compared to a random letter condition. Considering overlap in terms of interrupting task processes rather than letter identity, Experiment 2 found that performance was benefited when there was correspondence between the operation used in the secondary task and either that of the last goal realised, or that of the to-be-performed operation after interruption. Although the precise mechanism underlying such findings is yet to be determined, the experiments demonstrate that the degree of disruption caused by interruption is a function of the similarity of goals involved in the primary and interrupting tasks.

Labonté et al. (2024) examined how well participants' actual performance aligned with their perceived performance under different interrupted task conditions. They used a complex and dynamic above-water warfare microworld task that involved classifying the threat level of aircraft/neutralising hostile aircraft, with occasional interruptions to verify statements about mission status. Interruptions were either unexpected or occurred following an 8 s advance auditory warning. The disruptive impact of interruption on performance was demonstrated by various behavioural indices (classification speed, omissions, defensive effectiveness). Whilst previous research has found a protective effect of forewarning on actions immediately following interruption, this study showed that such a benefit is diluted when considering more global measures across a whole trial. Regarding subjective measures, participants were able to accurately rate their performance as lower with unexpected interruptions, but incorrectly perceived performance in the forewarned condition as being comparable to having no interruption at all. If interruption warning systems were to be implemented in the real world, it would be important that operators are aware of their continued vulnerability to interruption effects despite forewarning.

Sio et al. (2024) undertook two experiments that investigated whether problem solving performance of remote associates—that require a production of a single word that is semantically associated with three cue words (e.g. cues: manners, round, tennis; answer: *table*)—is influenced by switching between problems. Participants either worked on the same problem for 30 s (or until they solved it) or worked on each for 10 s (Experiment 1) or 15 s (Experiment 2) when they were randomly intermixed with other problems. In Experiment 1 the authors reported a negative effect of task switching on problem-solving accuracy but this was not observed in Experiment 2. Latency of correct responses was faster in the task switching condition in Experiment 2, but this was not observed in Experiment 1. Consistent across both experiments, the semantic similarity between adjacent responses was lower in the task switching against no switching condition, suggesting a broader search scope and multiple search paths. The failure of such broad search to facilitate RAT problem solving performance suggests that broad search, via shifts of focus between cues, may not be as crucial for RAT problem solving as previously thought (cf. Davelaar, 2015), although this does not rule out its potential importance in creative problem solving in general (see Nijstad et al., 2010). Aside from task switching, Sio et al. (2024) report that a strong determinant of problem solving success was the relatedness between the answer and the problem as revealed by a positive association between the two particularly when the number of competing responses within the search space was low.

Selective Attentional Processing Differences in Neurodivergent Populations

All articles within this subtheme focus on neurodivergent populations including children with autism spectrum condition and individuals with ADHD and compare the responses of these individuals with neurotypical groups (Zhang et al., 2024; Zhou et al., 2024) or between individuals with varying symptoms (e.g. of ADHD; Chronaki & Marsh, 2024; Elbe et al., 2024). All the studies use distractor paradigms to measure how different types of stimuli affect task performance. Zhang et al. (2024) and Zhou et al. (2024) use the remote distractor paradigm whilst Elbe et al. (2024) and Chronaki and Marsh (2024) use cross modal oddball paradigms. Zhang et al. (2024) and Zhou et al. (2024) investigate the effects of visual distractors, whilst Elbe et al. (2024) study the effects of auditory and tactile distractions and Chronaki and Marsh (2024) investigate emotional and neutral voice distractors. All studies address aspects of attention and cognitive control with Zhang et al. (2024) measuring involuntary attention biases and disengagement and Zhau et al (2024). measuring attentional orienting and control. Elbe et al (2024) and Chronaki and Marsh (2024) investigate attentional orienting to tactile (Elbe et al., 2024) and neutral (Elbe et al., 2024) and emotive (Chronaki & Marsh, 2024) oddballs (deviants). Group differences are reported in all articles across a range of stimulus type (e.g. face-like shape, objects and emotional voices) and an array of behavioural and subjective measures (e.g. error rates, response times, dwell times) and subjective measures (e.g. perceived performance, parent-rated hyperactivity) to assess the impact of distractions on participants.

By way of synopsis, in two experiments, Zhang et al. (2024) compared the disruptive potential of face-like and non-face-like visual stimuli in preschool children with and without autism spectrum condition using the remote distractor paradigm. In Experiment 1, the authors used simple shapes such as circles, triangles and rectangles that were either arranged in the form of a face (i.e. two circles representing the eyes, a triangle representing the nose, and a rectangle representing the mouth) or in a vertical line over one another. In Experiment 2, pictures of neutral faces, pictures in which the facial configuration of the individual components of the faces (eyes, nose, mouth) were mixed up, and pictures of blurred faces were used. In the remote distractor paradigm, the task for the participants is to fixate on the target stimulus and ignore any other visual stimuli presented alongside the target stimulus. In both experiments, a single black square inside an oval shape served as the target stimulus. Consistent across the two experiments, Zhang et al. (2024) found that children made more errors in trials where face or face-like stimuli were presented as distractor stimuli, indicating that both the involuntary attention of children with and without autism spectrum condition is biased towards facial stimuli. Despite these similarities, there were group differences with regard to the voluntary disengagement from face and face-like stimuli. Neurotypical children had longer latencies for scrambled faces, whilst children with autism spectrum condition took longer to shift their gaze away from face stimuli, which may lead to inefficient or delayed processing of social information.

Using eye-tracking, Zhou et al. (2024) investigated the impact of circumscribed interest (CI) distractors on attentional orienting in children with and without autism spectrum condition. Children with autism spectrum condition often display a bias in attention to specific objects such as vehicles, helicopters or instruments. But does this atypical preference mean that children with autism spectrum condition are also more distracted by these types of CI-related objects compared to non-CI-related objects? To find out, Zhou et al. (2024) combined the remote distractor paradigm with eye-tracking technology. The task for the children was to fixate on the target stimulus—which was the same on all trials (a picture of a sun)—and ignore any distractor stimuli presented alongside the target stimulus. Distractor stimuli were either CI-related objects (e.g. a picture of a helicopter) or non-CI-related objects (e.g. a picture of a plant). Group differences in saccade latencies, error rates, and corrective rates indicate weaker attentional control abilities in children with autism spectrum condition compared to neurotypical children. Whilst stimulus type did not have an effect on these three measures, dwell times (i.e. the time spent looking at a specific Area-of-Interest) for CI-related objects compared to non-CI-related objects were increased in children with autism spectrum condition, indicating some evidence of a bias in attention to these types of objects.

Elbe et al. (2024) examined whether individuals with low or high symptoms of ADHD differ in their response to auditory and tactile distractions. In a cross-modal oddball paradigm, distraction from the focal visual task by deviating sounds and vibrations did not differ between individuals with low and high ADHD symptoms. Additionally, both groups exhibited similar post-deviation effects and habituation to the distractions over time. However, the number of trials in which participants did not respond within the required time window was higher in the high-symptom group, possibly reflecting mind wandering away from the primary task. This nuanced pattern of results indicates that whilst there may be some differences in higher-level attention and mind wandering between individuals with low and high ADHD symptoms, these do not translate into significant differences in lower-level distraction by deviating sounds and vibrations from a visual focal task. Furthermore, the modality of distraction (auditory versus tactile) does not seem to differentially impact those with low or high ADHD symptoms.

Chronaki and Marsh (2024) used a cross-modal oddball paradigm wherein adults, adolescents and children performed a visual categorisation task while ignoring emotional voices (happy and angry) as oddballs and neutral voices as standard. All participants completed questionnaire measures of inattention and hyperactivity. The authors found that on the concurrent trial neither happy nor angry deviants slowed performance relative to the neutral control, that is, there was no deviation effect. However, on the trial immediately following the deviant, participants were slower to respond to targets following an angry deviant than a neutral voice. Further children were slower to respond to targets following angry and happy deviants relative to neutral voices, whilst adults were slower to respond to targets on neutral trials preceded by angry deviants compared to both happy deviants and neutral voices. Thus adults demonstrated a specific threat-related effect to angry voices. There were no between-conditions effects for adolescents. In a multiple regression analysis, parent-rated hyperactivity scores were associated with reaction times to targets that were preceded by angry but not happy nor neutral voices in children. Further, for post-deviant distraction, hyperactivity in children was positively associated with reaction times on neutral trials preceded by a happy and angry deviant, but not a neutral voice. The authors propose that threat-related (e.g. angry) stimuli may be preattentively processed in children with hyperactivity and support the notion that individuals with ADHD demonstrate differences in early sensory (e.g. preattentive) emotion processes (see also Chronaki et al., 2015).

Conclusion

The papers on interruptions and task switching contribute to our understanding of multiple goal management, including metacognitive awareness and strategy changes under conditions of multitasking. The paper on task switching (Sio et al., 2024) suggested that switching between two tasks does not always lead to performance disruption, and can yield subtle changes in search strategies through the problem space. Using an interrupted task paradigm, strategy changes were also addressed by Altmann & Hambrick (2024): Under conditions in which internal or external support is lacking, participants engage in compensatory strategies to enhance memory and facilitate performance in line with an implicit task optimum. Whilst this might suggest a metacognitive awareness of performance, Labonté et al. (2024) found that individuals were poorly calibrated regarding estimates of their multitasking abilities; the degree to which forewarning could mitigate negative interruption effects was significantly overestimated. Finally, Piątkowski et al. (2024) demonstrated how multiple goal management can be influenced by the similarity between primary and secondary task goals.

The four papers focusing on neurodivergent populations provided mixed evidence for selective attentional processing differences depending on the behavioural measure and adopted methodology. This should prompt a more detailed look at the specific differences in distraction associated with specific conditions such as ADHD, autism, and hyperactivity. Specifically, these conditions may affect specific functions in the control of distraction such as control of emotional distraction rather than distraction at a more general level, and some lower-level functions may remain unaffected by these conditions and may thus not differ between individuals with or without symptoms. Identifying differences in selective attention processes in atypical as compared with typical populations can lead to programmes aimed at developing attentional control skills, particularly in emotional contexts and can help to identify problematic sources of distraction which could, for example, be used to remove particularly problematic sources of distraction from learning environments.

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