

The Effect of Attention on the Release of Anticipatory Timing Actions

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A loud auditory stimulus (LAS) presented during movement preparation can result in an earlier than normal movement onset. This effect had initially been assumed to be independent of the sensorial modality people attended to trigger their responses. In 2 experiments, we tested whether this assumption was warranted. In Experiment 1, we employed a timed response paradigm in which participants were cued in relation to the precise moment of movement onset of their motor responses. In the visual task, participants were cued about movement onset via visual cues on a monitor screen. In the auditory task, participants were cued about movement onset through tones delivered via headphones. During both tasks, we delivered an unexpected LAS 200 ms prior to movement onset. We found that the responses were initiated earlier by the LAS in the auditory task in relation to the visual task. In Experiment 2, we presented participants with a sequence of tones and flashes interleaved. The participants' task was to ignore either the tones or the flashes and make a movement in sync with the last tone or flash. The results showed that when participants had to ignore the task-irrelevant tones in the background, the early responses were much reduced. In contrast, when participants had to pay attention to the tones and ignore the flashes, the early release of anticipatory actions was robust. Our results indicate that attention to a specific sensorial modality can affect the early release of motor responses by LAS.

Keywords: attention, auditory stimulus, motor control, movement initiation, preparation

There has been a growing interest in behavioral neuroscience to understand the mechanisms by which loud auditory stimuli (LAS) can facilitate the initiation of motor actions (see Carlsen, Maslovat, Lam, Chua, & Franks, 2011; Valls-Solé, 2012 for reviews). The early release of actions by LAS is a robust phenomenon and has been demonstrated in simple reaction time (RT) tasks (Carlsen, Chua, Inglis, Sanderson, & Franks, 2009; Carlsen & Mackinnon, 2010; Marinovic, de Rugy, Lipp, & Tresilian, 2013), hitting (Tresilian & Plooy, 2006), postural adjustments (Delval et al., 2012; MacKinnon et al., 2007; Rogers et al., 2011), head rotations (Oude Nijhuis et al., 2007), and saccadic eye movements (Castellote, Kumru, Queralt, & Valls-Solé, 2007).

Despite the theoretical interest in the facilitation of voluntary movements by LAS in health and disease (Honeycutt & Perreault, 2012; Nonnekes et al., 2014; Thevathasan et al., 2011), only one study has been conducted to examine the role of type of sensorial modality participants paid attention to on the release of motor actions (see Carlsen, Lam, Maslovat, & Chua, 2011). In this study,

Carlsen and colleagues (2011) found that simple RTs were faster for auditory than for visual imperative stimuli. This modality specific difference, however, was virtually absent when a loud acoustic stimulus (124dB) was presented unexpectedly during the auditory and visual tasks. This prompted the authors to suggest that the LAS does not speed processing along the normal stimulus-response channels. Instead, they favored the view that prepared actions are activated via a separate, faster neural pathway. Activation of this separate pathway, therefore, should not be affected by attention, which is known to affect the human eyeblink reflex (see, e.g., Filion, Dawson, & Schell, 1998; Lipp, Blumenthal, & Adam, 2001). This conclusion is consistent with evidence showing that the eyeblink reflex and the release of motor actions are mediated by different physiological mechanisms (Kumru, Valls-Solé, Kofler, Castellote, & Sanegre, 2006; Maslovat, Kennedy, Forgaard, Chua, & Franks, 2012; Valls-Solé, Kofler, Kumru, Castellote, & Sanegre, 2005). Carlsen and colleagues' results, however, could also be explained by a floor effect as RTs when the LASs were delivered were remarkably short for both auditory and visual tasks (≈ 70 ms).

Even though salient unexpected stimuli may be automatically processed by the brain (Yantis & Jonides, 1990), there is reasonable evidence that top-down processes (Pashler, Johnston, & Ruthruff, 2001; SanMiguel, Corral, & Escera, 2008) and/or sensorial expectations (Bendixen, Schroger, & Winkler, 2009) can mediate neural responses to transient stimuli. Moreover, it has been reported in other contexts that attention can modulate early precortical auditory processing (Sörqvist, Stenfelt, & Rönnerberg, 2012). Thus, it seems intuitive that attention could also modulate the triggering of voluntary responses by LAS in both cortical and

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subcortical levels. This led us to reexamine whether the sensorial modality to which people attend to could modulate the effect of LAS on the release of motor actions. This will inform not only whether attention is important for the release of motor actions by sound during preparation, but also lead to a greater understanding about the overlapping physiological mechanisms subserving the eyeblink reflex and the initiation of motor actions. Here, we investigate the effect of attending to different sensory modalities on the facilitation of movement using anticipatory timing actions. We predict that when anticipatory timing performance relies on auditory cues, the magnitude of the effect is larger than that we observe for timing performance depending on visual cues.

Experiment 1

To test our prediction, we employed the timed response paradigm developed by Ghez and colleagues (Ghez, Hening, & Favilla, 1989, 1990), where participants are trained to initiate their actions in synchrony with the last of a sequence of tones or flashes. An unexpected LAS was presented between the last and second last

timing cues. We show that attending to the same sensorial modality of the temporal cue is important to determine the magnitude of the effect of LAS on the release of anticipatory actions.

Method

Participants. Twelve volunteers (mean age 24.5 years old, $SD = 6.41$; 7 females) participated in the experiment. All of them stated that they were right-handed and had normal or corrected-to-normal vision. Participants gave informed consent prior to commencement of the study, which was in accordance with the Declaration of Helsinki and approved by the local Ethics Committee of the University of Queensland.

Task. Visual task: Participants were required to make a short and brief abduction of the right index-finger in synchrony with the onset of the last of a sequence of four (500 ms apart from each other) flashes (red, 200×200 pixels) appeared on a 19-in. monitor screen (60 Hz refresh rate, 1280×1024 resolution) as depicted in Figure 1 (Left). Participants were positioned 0.9 m away from the monitor. The duration of the flash was 3 frames (≈ 50 ms). Visual

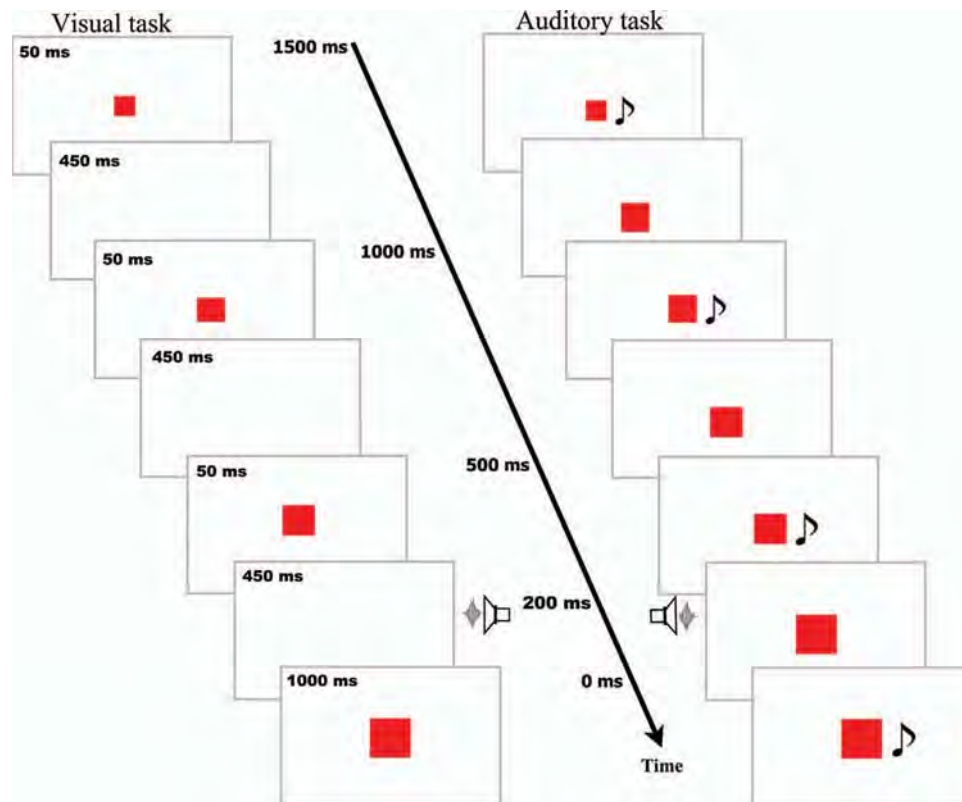


Figure 1. Sequence of events during a trial. Left - Visual task: The first flash served as a warning signal and lasted for 50 ms. Subsequent flashes were presented 500 ms apart. The second and third flash also lasted 50 ms. Participants were asked to make an abduction of the index finger (e.g., index finger moves away from the index finger) in sync with the last flash. The last flashed rectangle remained on the screen for 1,000 ms. Right - Auditory task: The first tone served as a warning signal and lasted for 50 ms. Subsequent tones were presented 500 ms apart and also lasted 50 ms. Participants were asked to make an abduction of the index finger in sync with the last tone. The red rectangle remained on the screen for the duration of the trial. For both tasks, on probe trials loud auditory stimuli (LASs) were presented between the third and fourth timing cues (10% of total). Participants were asked to ignore the LAS and abduct the finger at the appropriate time. The color version of this figure appears in the online article only.

stimuli and sounds were generated with Cogent 2000 Graphics running in MATLAB 7.5.

Auditory task: The participants' task was the same as in the visual task, but the timing of the index-finger abduction had to be synchronous with the onset of the last of a sequence of four tones (pure tone, 80dB). Participants were asked to look at a red square (200 × 200 pixels) at the center of the monitor screen (see Figure 1, Right), as its appearance indicated the trial was about to begin. The red square remained on the screen while participants listened to the auditory cues via high-quality headphones.

Loud auditory stimuli. The LAS were bursts of 50-ms broadband white noise with a rise/fall time shorter than 1 ms. Stimuli were generated on a digital computer and presented binaurally via high-fidelity stereophonic headphones (Sennheiser model HD25-1 II; frequency response 16 Hz–22 kHz; Sennheiser Electronics GmbH & Co. KG, Wedemark, Germany). The input signal to the headphones had a bandwidth of approximately 10 Hz–30 kHz. Auditory stimuli had a peak loudness of 99 dB. The LAS intensity was the same in both task and was measured with a Brüel and Kjær sound level meter (Type 2205, A weighted; Brüel & Kjær Sound and Vibration Measurement, Naerum, Denmark) placed 2 cm from the headphone speaker.

Procedures and design. Before the experiment started, participants were presented the LAS two times. Prior to the experimental block of trials, the participants were trained to abduct their index fingers at the correct time. Participants performed 40 trials during practice before each experimental condition. Feedback was provided to help participants to learn the correct time of movement onset. In each experimental condition, participants performed 100 trials where they tried to synchronize their contractions with the last flash (Figure 1, Left) or tone (Figure 1, Right). On 10 of those (10% of the total number of trials), a LAS was presented, and participants were asked to ignore it and perform the task normally. LAS trials were pseudorandomly distributed and could never occur sequentially. Feedback was provided in all trials except for those in which the LASs were presented so as to keep performance consistent throughout the experimental conditions. The onset time of the LAS was always 200 ms prior to the expected time of movement onset (or last flash or tone). Participants performed the visual or auditory task in a counterbalanced order.

Data analysis. The variables of interest were temporal error, peak torque, and torque duration. Temporal error was defined as the difference between movement onset and the time the last flash or tone was physically presented (negative = early). Movement onsets were estimated from the tangential speed time series (derived by numerical differentiation from the filtered torque data) using the algorithm recommended by Teasdale, Bard, Fleury, Young, and Proteau (1993). Peak torque was defined as the maximum value of the torque signal. Torque duration was defined as the time between movement onset and movement offset. Movement offset was estimated using the same algorithm used to determine movement onset. Means of temporal error, peak torque, and torque duration obtained in control trials and in LAS trials were compared using paired tests. All variables were first checked for normality using the Shapiro-Wilk test. When the assumption of normality was met we tested for differences between means using paired *t* tests. When the normality assumption was violated we employed the Wilcoxon's test to compare means. Alpha was set to 0.05 for all comparisons. We report 95% confidence intervals for

the difference between means. Following Drummond and Vowler's (2012) suggestion for data analysis, we also present the results of permutation tests (not presented when comparing against a reference value of zero), which do not depend on the assumption of normality. Data analysis was conducted using R statistical software and StatBoss (Lew, 2008).

Results

There was no statistical difference between the means for temporal error in the auditory ($x = -13.5$ ms, $SE = 6.5$ ms) and visual ($x = -21$ ms, $SE = 6.7$ ms) tasks in control trials, $t(11) = 1.29$, $p = .22$, 95% CI $[-5.35, 20.60]$, permutation test: $p = .23$, suggesting timing performance in control trials was to a great extent comparable between the two tasks. As expected, the LAS have a significant effect in both tasks (one sample *t* test $M = 0$; auditory: $t(11) = 7.32$, $p < .0001$, 95% CI $[-82.39, -44.31]$; visual: $t(11) = 4.60$, $p = .0007$, 95% CI $[-53.88, -18.98]$, indicating that the early release of the prepared actions occurred in both tasks. More importantly, the change in temporal error (control error – LAS error) was statistically larger for the auditory than for the visual task, $t(11) = 2.95$, $p = .013$, 95% CI $[-46.96, -6.87]$, permutation test: $p = .015$, as shown in Figure 2 (A). As expected, an analysis of variance on the temporal error showed a statistically reliable interaction between type of trial (control vs. LAS) and task (visual vs. auditory), $F_{(1, 11)} = 8.73$, $p = .013$.

For peak torque, means did not differ statistically for the two tasks in control trials, $t(11) = 0.59$, $p = .57$, 95% CI $[-0.16, 0.09]$, permutation test: $p = .61$. Changes in peak torque were, however, statistically different from a reference value of zero, auditory: $t(11) = 2.53$, $p = .028$, 95% CI $[0.006, 0.08]$; visual: $t(11) = 2.39$, $p = .036$, 95% CI $[0.004, 0.1]$, indicating response vigor increased with the LAS presentation. However, there was no difference between tasks for peak torque means when the LAS was presented, $t(11) = 0.46$, $p = .65$, 95% CI $[-0.07, 0.04]$, permutation test: $p = .65$.

For torque duration, we found no difference for the two tasks during control trials $t(11) = 0.69$, $p = .50$, 95% CI $[-41.47, 79.30]$, permutation test: $p = .50$. In relation to control trials, torque duration did not change statistically from a reference value of zero when a LAS was presented, one sample *t* test auditory: $t(11) = 1.69$, $p = .12$, 95% CI $[-56.66, 7.32]$; one-sample Wilcoxon signed-ranks test visual: $Z = 1.72$, $p = .09$, 95% CI $[-31.5, 4.75]$, indicating torque duration was not greatly affected by the LAS. The change in torque duration means did not differ statistically between tasks, $Z = 0.55$, $p = .62$, 95% CI $[-41.9, 35.9]$, permutation test: $p = .69$.

Experiment 2

In Experiment 1, we showed that the effect of auditory stimulation on the release of anticipatory depends on the sensorial modality that the participants were attending to make their responses. Two hypotheses could explain the pattern of results obtained:

Hypothesis 1: The presentation of the auditory cues could generate an automatic expectation—no voluntary attention required—of the next tone and then the unexpected LAS

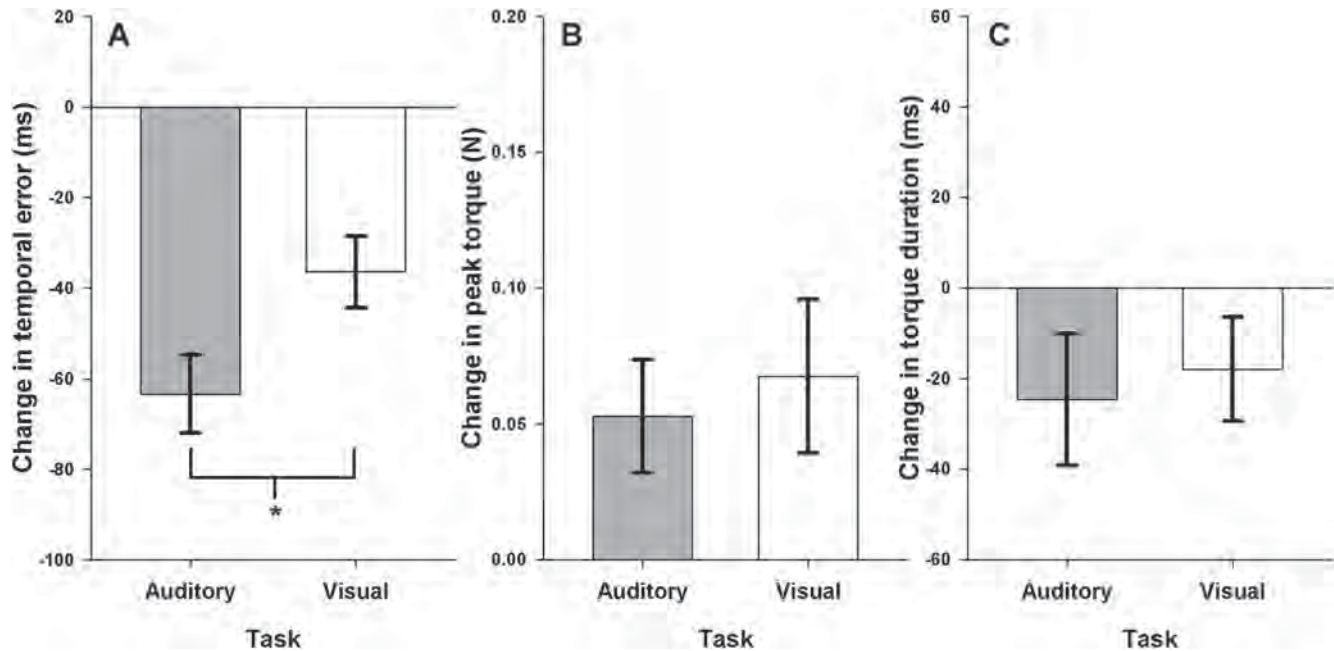


Figure 2. A-Change in temporal error from control to loud auditory stimulus (LAS) trials. B-Change in peak torque from control to LAS trials. C-Change in torque duration from control to LAS trials. Error bars show the standard error of the mean. * Statistically significant differences between means.

could cause a larger neural response in that sensorial channel (Bendixen et al., 2009).

Hypothesis 2: Attention to the auditory cues could enhance the effects of the LAS.

If we presented auditory cues during a visual task, the first hypothesis would predict the magnitude of the LAS to be the same for the auditory and visual tasks. Thus, a statistical difference in the magnitude of the effect (e.g., how early participants moved) between the visual and the auditory tasks would strongly suggest Hypothesis 1 is unlikely to be correct. In Experiment 2, we sought to test the prediction of Hypothesis 1 that violations of the expected timing and characteristics of the auditory signal could generate larger neural responses in the auditory channel (see Bendixen et al., 2009; Widmann, Kujala, Tervaniemi, Kujala, & Schroger, 2004).

Method

Twelve volunteers (mean age 27.9 years old, $SD = 4.83$, 10 men) participated in Experiment 2. All of them were right-handed and had normal or corrected-to-normal vision. Participants gave informed consent prior to commencement of the study, which was in accordance with the Declaration of Helsinki and approved by the local Ethics Committee of the University of Queensland.

Task

Details of the experimental task were similar to those of Experiment 1 with the following exceptions: Flashes and tones were interleaved in all trials (see Figure 3). The sequence was always

initiated with a tone regardless as to whether participants responded in synchrony with the last tone or flash. Tones and flashes were presented 300 ms apart, thus the interval between tones (or flashes) was 600 ms (100 ms longer than in Experiment 1). Participants performed the visual or auditory task in a counterbalanced order. The unexpected LAS was presented between the third and fourth (200 ms before the last cue as for Experiment 1) tones or flashes, depending on the requirement of the task as shown in Figure 3. Participants were explicitly told to ignore either the tone or the flash to perform the tasks.

Results

There was a small but statistically reliable difference between means for the temporal error in the auditory ($x = 9.5$ ms, $SE = 5.6$ ms) and visual ($x = -11.5$ ms, $SE = 4.9$ ms) tasks in control trials, $Z = 2.03$, $p = .045$, 95% CI $[-40.24, -0.62]$, permutation test: $p = .037$. In contrast to Experiment 1, the LAS resulted in early responses in the auditory task, one-sample t test $M = 0$; $t(11) = 7.99$, $p < .0001$, 95% CI $[-62.90, -35.70]$, but not in the visual task, $Z = 1.88$, $p = .065$, 95% CI $[-45.80, 6.70]$, indicating that the early release of the prepared actions occurred more strongly in the auditory task. Also, the change in temporal error (control error – LAS error) was statistically larger for the auditory than for the visual task, $Z = 2.11$, $p = .037$, 95% CI $[-51.99, -3.75]$, permutation test: $p = .02$, as shown in Figure 4 (A). Thus, only the auditory timing task resulted in a robust effect of the LAS on movement onset time. Similarly to Experiment 1, the analysis of variance on the temporal error showed a statistically significant interaction between type of trial and task, $F_{(1, 11)} = 6.83$, $p = .024$.

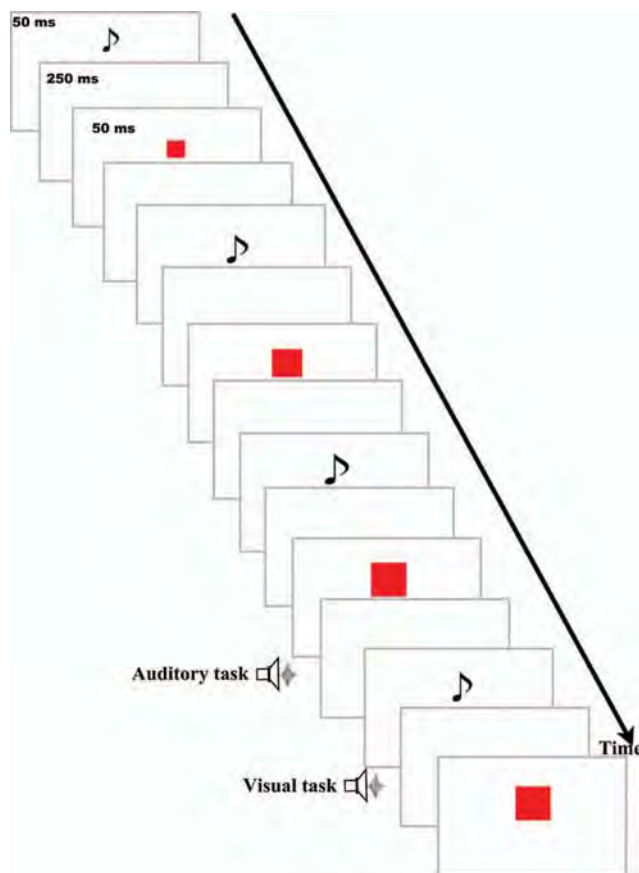


Figure 3. Sequence of events during a trial in Experiment 2. Short tones and flashes (50 ms duration) were alternated. Each trial contained four tones and four flashes. In the auditory task (sync your movement with the last tone), an unexpected loud auditory stimulus (LAS) was presented 200 ms prior to the last tone. In the visual task, the LAS was presented 200 ms prior to the last flash. The color version of this figure appears in the online article only.

For peak torque, means did not differ statistically for the two tasks in control trials, $t(11) = 0.59$, $p = .19$, 95% CI $[-0.02, 0.12]$, permutation test: $p = .20$. Changes in peak torque were again statistically different from a reference value of zero, auditory: $t(11) = 3.05$, $p = .01$, 95% CI $[0.04, 0.25]$; visual: $t(11) = 5.91$, $p = .0001$, 95% CI $[0.07, 0.16]$, indicating response vigor increased with the LAS presentation. However, there was no difference between tasks for peak torque means when the LAS was presented, $t(11) = 0.68$, $p = .50$, 95% CI $[-0.11, 0.15]$, permutation test: $p = .89$.

For torque duration, we found no difference for the two tasks during control trials, $Z = 1.64$, $p = .11$, 95% CI $[-2.75, 49.90]$, permutation test: $p = .07$. In relation to control trials, torque duration did not change significantly from a reference value of zero when a LAS was presented, one-sample Wilcoxon signed-ranks test auditory: $Z = 0.47$, $p = .48$, 95% CI $[-18.90, 20.24]$; visual: $Z = 0.74$, $p = .66$, 95% CI $[-6.49, 40.75]$, indicating torque duration was not affected by the LAS. The mean change in torque duration between tasks was not statistically reliable, either, $Z = 0.47$, $p = .12$, 95% CI $[-3.0, 38.7]$, permutation test: $p = .07$.

Discussion

Our studies aimed to examine the effect of attending to different sensorial modalities on the release of a movement by a loud acoustic stimulus during the final preparation stage of an anticipatory timing action (Marinovic, Plooy, & Tresilian, 2008; Marinovic, Plooy, & Tresilian, 2009; Marinovic, Reid, Plooy, Riek, & Tresilian, 2011). Previous research had suggested that attending to a particular sensorial modality to initiate our actions does not affect how early the response can be released (Carlsen, Lam et al., 2011) but the results could also be explained by a floor effect caused by very fast responses to the LAS. Here, we reexamined this issue. Critical to do so, we employed the timed responses paradigm (Ghez et al., 1989, 1990) in which participants are trained to time their actions with the last of sequence of tones or flashes. Thus, participants should never react to the last tone/flash but, instead, predict its appearance and move in anticipation. Our results in both experiments suggest that participants were indeed anticipating the last cue as the temporal errors in control trials of both tasks were small. Additionally, there was no difference in the timing of movement onset for control trials between the two tasks in Experiment 1, suggesting that the visual and auditory cues for movement anticipation worked equally well for our participants. As predicted, we found that the timing of the participants' responses in the auditory task were earlier than those obtained for the visual task (see Figure 2A). These results could be explained by the effects of voluntary processing (e.g., top-down) of auditory inputs or by the effect of a violation of the expected auditory input when unexpected loud auditory stimuli were delivered between the third and fourth cues in the auditory task. We examined the latter possibility in Experiment 2.

In Experiment 2, we forced participants to prioritize the processing of either visual or auditory cues by presenting both types of temporal cues in all trials. Thus, participants had to attend to one sensorial modality while cues on the other modality occurred on the background. Interestingly, we observed that the early release of motor actions did not occur for all participants when participants synchronize their actions to the visual cues. Conversely, the early release was again robust when participants attended to the auditory cues. These results speak against the hypothesis of an increase in neural responses in the auditory channel due to a violation of the expected input in that modality. If participants engaged automatically in the prediction of auditory signals (Bendixen et al., 2009; see also Widmann et al., 2004), the unexpected LAS would violate the expectations in both tasks as auditory cues were either in the background or essential for the timing task. Therefore, the effect should be similar in both tasks under this hypothesis.

Our results also showed that the pattern of results obtained in the timing of movement onset could not be explained by the combination of startle reflex-like responses on the index finger combined with a later voluntary contraction of the same finger as this would increase torque duration. The results we obtained, if anything, indicated a tendency for torque duration to decrease in the presence of the LAS (Experiment 1). Peak torque, on the other hand, was significantly larger for both tasks when the LAS was presented in both experiments. This is a common finding in studies using LAS to release motor actions (Kumru & Valls-Solé, 2006; Marinovic et al., 2013; Tresilian & Plooy, 2006) and can be accounted for by the activation model we have put forward re-

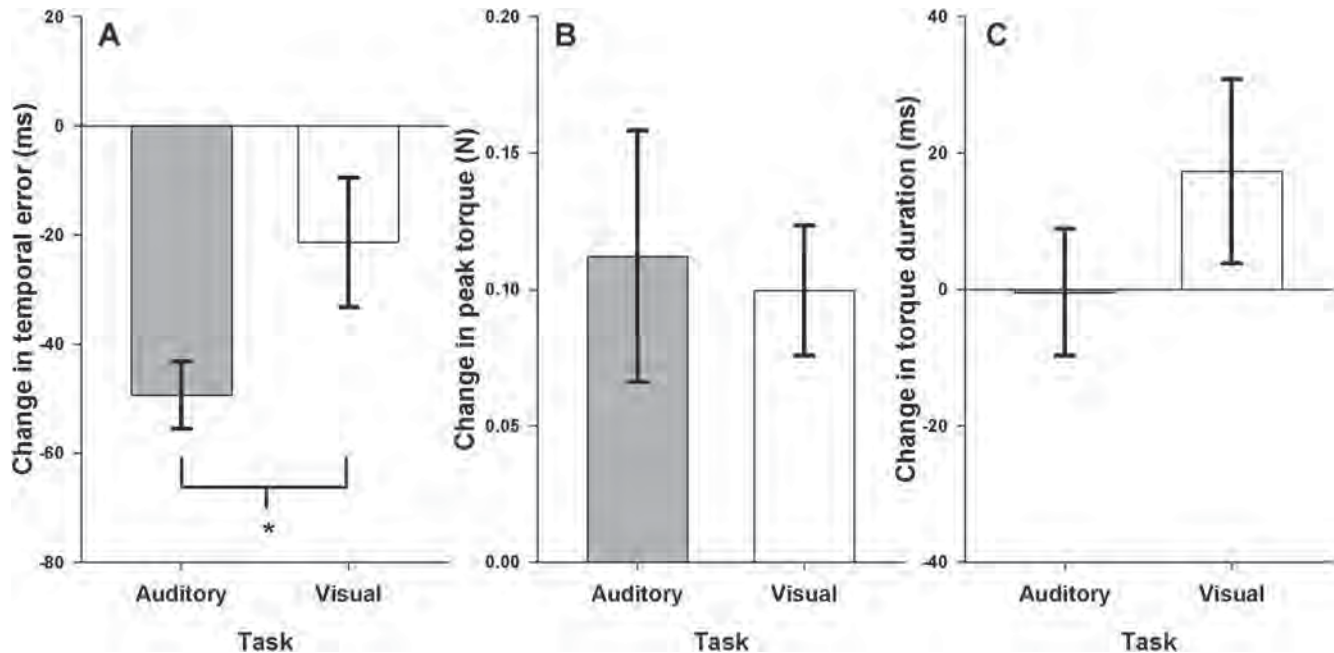


Figure 4. A-Change in temporal error from control to loud auditory stimulus (LAS) trials. B-Change in peak torque from control to LAS trials. C-Change in torque duration from control to LAS trials. Error bars show the standard error of the mean. * Statistically significant differences between means.

cently elsewhere (Marinovic et al., 2013; Marinovic, Tresilian, de Rugy, Sidhu, & Riek, 2014). More specifically, we have suggested that the activity evoked by an LAS adds to that building up during preparation. When the combined activity of these two sources surpasses threshold for command generation the response is released early and its magnitude depends on the amount to which the threshold is surpassed (Marinovic et al., 2013).

One may question whether other processes such as sensitization might have affected our results. The literature on the StartReact effect, however, suggests that while the early release of motor responses can remain unaffected, the startle reflex (e.g., sterno-cleidomastoid [SCM] activation) is habituated over repeated trials (see Maslovat, Carlsen, & Franks, 2012; Valls-Solé, Valldeoriola, Tolosa, & Nobbe, 1997). Moreover, in our Experiment 2, where tones were presented in all trials during the auditory and visual tasks, the magnitude of the effect was reduced in the visual task, but not the in auditory task. Thus, it seems more likely that the repetition of the tones in each trial would increase habituation, not sensitization. One should also note that the larger effects of attending to the auditory modality we report here are likely to depend on the intensity of the LAS. For very loud stimuli, Carlsen and colleagues (2011) estimated that the difference between the auditory and visual task was 3.5 ms (auditory faster). This effect is in the same direction of our results, but theirs may have been underestimated as it would be physiologically implausible to expect that responses could be much faster than they were observed (67.7 ms) for an auditory stimulus of 124dB. Therefore, attention may be even more important in terms of the magnitude of the effect than we could estimate using 99dB as a movement triggering stimulus.

We should also point out here that Carlsen and colleagues (2011) obtained their results in a simple RT task, whereas our

results were obtained using an anticipatory timing task. While part of the preparatory stages leading to movement onset can be identical, it is quite clear that the movement triggering event differs between these tasks (see Tresilian & Plooy, 2006). In RT tasks, movement onset is triggered externally by either the auditory or visual imperative stimulus. In anticipatory tasks, the movement triggering event is generated internally and based on an estimation of the timing of an external event. Thus, whether or not attention is important in RT tasks remains to be confirmed, but one should be mindful of potential flooring effects when using excessively loud triggering stimuli as we discussed above.

Carlsen and colleagues (Carlsen, Dakin, Chua, & Franks, 2007) have made a distinction between the effects of stimulus intensity and startled responses. More specifically, they proposed that truly startled responses require SCM activation, and when this occurs, the latency until movement onset does not depend on stimulus intensity. Conversely, the time to trigger a response that is not startled does depend on stimulus intensity: the greater the intensity, the sooner the response. Our results are consistent with the effects of stimulus intensity albeit we used the same intensity in both tasks (99dB). Carlsen and colleagues (Carlsen et al., 2007) also suggested that the eyeblink may be a poorer indicator of a startled response, even though these are much more easily elicited. Thus, we made no attempt to measure SCM or eyeblink responses in our study as the percentage of LAS induced activation of SCM would be small with the LAS intensity we adopted (see Carlsen et al., 2007). Consequently, we cannot be sure whether participants were more likely to have SCM activation in the auditory task than in the visual task. Future studies should investigate whether attention to specific sensory modalities can modulate the proportion and/or magnitude of SCM activation during motor preparation.

In contrast to previous research using RT tasks (see Carlsen, Lam et al., 2011), our results clearly indicate that the effect of attending to different sensorial modalities we observed for the early release of motor actions has an effect very similar to that reported by studies interested in the human startle eyeblink reflex. More precisely, previous research on the startle eyeblink reflex has consistently demonstrated that the reflex is facilitated when participants pay attention to auditory input (Bohlin & Graham, 1977; Bohlin, Graham, Silverstein, & Hackley, 1981) and inhibited when attention is directed to a different sensorial modality (Anthony & Graham, 1985; Anthony & Putnam, 1985; Balaban, Anthony, & Graham, 1985). Therefore, even though the consensus seems to be that startle eyeblink reflexes and the release of motor actions by sound ultimately have separate physiological pathways (Kumru et al., 2006; Maslovat, Kennedy, et al., 2012; Valls-Solé et al., 2005), attention seems to affect the two phenomena in the same manner. Our results thus demonstrate that task instructions can either enhance or mask the effects of LAS on the release of motor actions. If task instructions require people to attend to the auditory information, one might be able to elicit larger effects with relatively lower intensity auditory noise. This is of relevance to those studying motor preparation using acoustic probes as stimulus intensity cannot be increased indiscriminately until SCM is activated, but task instructions can be set to enhance the effects of LAS on movement facilitation.

Conclusion

In summary, our results indicate that the intensity of the auditory stimulus need not be of high intensity to obtain robust effects; early responses can be elicited reliably with relatively low stimulus intensity. Even though there seems to be a physiological separation between the pathways responsible for the early release of motor responses and the eyeblink reflex induced by LAS, attention can modulate both effects similarly.

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