

Electrophysiological correlates of the somatotopically organized tactile duration aftereffect

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adaptation to sensory events of long or short duration leads to a negative aftereffect, in which a neutral target event of median duration following the adaptation will be perceived to be shorter or longer than is actually the case. This illusion has been observed in visual, auditory, and tactile modalities. This study used event-related potentials (ERPs) to examine the tactile duration aftereffect, using the contingent negative variation (CNV) and the late positive component (LPC) as a way to characterize the temporal processes. The tactile duration adaptation was found to induce a significant aftereffect. Within a somatotopic frame of reference, the CNV in the contralateral scalp and the LPC in the fronto-central scalp were both modulated by the tactile duration adaptation. Specifically, adaptation to a short tactile duration increased the CNV and LPC amplitudes, whereas adaptation to a long tactile duration decreased them. This modulation was contingent on the topographic distance between fingers, which was only observed when the adapting and test fingers were consistent or adjacent, but not homologous. In sum, these results reveal a coherent behavioral electrophysiological link in the somatotopically organized tactile duration aftereffect.

1. Introduction

Our brain adapts to temporal information to maintain a coherent representation of the world (Burr et al., 2002; Lu et al., 2010; Johnston et al., 2011). One such example is the well-documented phenomenon of duration adaptation (Eron et al., 2010; Li et al., 2011; Lu et al., 2011). In duration adaptation, the perceived duration of a sub-second event of medium physical duration is biased by repetitive exposure to a relatively short or long sensory stimulus. This duration aftereffect hence supports the hypothesis of "duration channels" (Eron et al., 2010).

Whereas the duration adaptation has been extensively studied in audition and vision, whether the somatosensory system can similarly adapt to changes in duration remains largely unknown. To address this, we recently conducted several behavioral experiments in which tactile duration adaptation (Li et al., 2011). In this study, participants were first adapted to a long (1000 ms) or short (200 ms) duration tactile stimulus,

and then completed different temporal tasks such as duration discrimination and reproduction. The results showed that adaptation to a relatively long tactile duration shortened the perceived duration of subsequent tactile stimuli, while adaptation to a relatively short tactile duration lengthened them. Moreover, the tactile duration aftereffect is modality specific, tuned around the adapting duration, and dependent on the topographic distance between fingers – in other words, it is a robust duration adaptation mechanism in the somatosensory system. The behavioral findings indicated the modality specific timing mechanisms, and revealed that early somatosensory areas play an essential role in the perception of sub-second tactile duration. Moreover, little is known about the temporal dynamics of the duration aftereffect.

In the channel-based model, duration information is encoded and mediated by duration-selective channels, with "channel-based" analysis predicted by the duration-tuned neurons in the brain (Eron et al., 2010). Adaptation to a duration-selective channel diminishes the responses of relevant channels, thus modifying the subsequent temporal encoding of

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these duration channels and resulting in the duration aftereffect. Consistent with this hypothesis, a previous study has demonstrated that the visual duration adaptation modulates subsequent temporal encoding (Li et al., 2019). Moreover, duration perception involves a series of temporal information processing, including the earlier encoding as well as later stages such as temporal memory storage and decision making (Libbon, 2019; Reisman, 2019). In this information processing perspective, whether and how the tactile duration adaptation affects subsequent temporal encoding or later stages in the process (e.g., temporal memory) is far from clear. In the behavioral characteristics of the tactile duration aftereffect (Li et al., 2019), by using electrophysiological recording with electroencephalography (EEG), we predicted that the effect of sub-second tactile duration adaptation should operate on modality-specific mechanisms specific to tactile modality and reveal the distributed aspects of temporal information processing across differential but featured stages (Urai et al., 2019).

Among EEG measures, the contingent negative variation (CNV) is particularly implicated in cognitive processes associated with time keeping. The CNV is a slow negative going wave mainly elicited in the fronto-central scalp and unfolds as a duration is being processed. Previous studies have extensively investigated the role of the CNV in temporal processing in different modalities, including the tactile modality (Acar and Vidal, 2019; Agai et al., 2019; Feuty et al., 2019). Despite existing debates on the perceptual and cognitive functions of the CNV, studies have found that CNV amplitude reflects the perceived duration of a stimulus (Bendi et al., 2019; Acar et al., 2019; Jäner et al., 2019).

Larger amplitudes are associated with perceived longer passages of time. Hence, the CNV has been described as an "online index of timing" (Acar and Vidal, 2019; G and Enney, 2019). Thus, this mechanism provides a means to investigate the neural correlations of temporal illusions. For example, previous studies have demonstrated that the visual duration adaptation (Li et al., 2019), but not icter-induced time dilation (Erbst et al., 2019), modulates the temporal encoding indexed by the CNV amplitude.

Event-related potential (ERP) components that develop after the presentation of a stimulus are also involved in temporal processing (Ononozic and Anin, 2019; Lindbergh and Joffe, 2019; Aul et al., 2019; Arantino et al., 2019). For example, Ononozic and Anin (2019) demonstrated that the amplitude of ERP components evoked by a sound terminating a comparison interval is a better predictor of subjective duration than the preceding CNV. This also suggests that timing processes continue after CNV resolution. Moreover, certain post-stimulus positive components have been proposed to be

related to later stages of time processing. For example, the time-related late positive component (LPC) is associated with temporal decision making (Aul et al., 2019). In addition, it has been suggested that the LPC, appearing after the offset of the comparison interval, is involved in working memory processes (Arantino et al., 2019). Here, we hypothesize that the CNV and post-stimulus components can be used to probe the tactile duration aftereffect, and to further examine how that adaptation modulates subsequent tactile temporal processing. Previously, we found that the visual duration adaptation modulates subsequent visual temporal encoding (Li et al., 2019). Thus, we expected to find a similar

The E as calculated by fitting a psychometric function using logistic regression response level on the psychometric function, ig for each subject, the E value for the no adaptation condition was subtracted as a baseline B from E values in the adaptation conditions respectively i.e., adapt to a short duration on the consistent C , homologous L , and adjacent L fingers adapt to a long duration on the consistent CL , homologous L , and adjacent L fingers see also the procedure section these differences were defined as aftereffect magnitudes for different adaptation conditions ig B the resulting s were positive when the adaptation measure was greater than the baseline measure, suggesting that the tactile duration adaptation expanded the perceived duration of subsequent tactile stimuli in contrast, negative s indicated that the perceived tactile duration was contracted by the adaptation s were analyzed with the repeated measures Greenhouse-Geisser correction as applied considering violation of sphericity assumption

adapting duration short, long \times adapting location consistent, adjacent, homologous repeated measures as implemented the main effect of the adapting duration was significant $F(1, 17) = 10.8, p < .01, \eta^2 = .44$, the main effect of the adapting location was marginally significant $F(2, 34) = 3.1, p = .05, \eta^2 = .30$, and their interaction was significant $F(2, 34) = 4.1, p = .02, \eta^2 = .34$ furthermore, simple effect analysis showed that the s in the C condition was significantly larger than that in the CL condition $p < .05$, Cohen's $d = 0.4$, and the s in the CL condition was significantly larger than that in the L condition $p = .01$, Cohen's $d = 0.3$ moreover, there was no significant difference between C and L conditions $p = .15$, Cohen's $d = 0.1$ these results suggest that the tactile duration adaptation resulted in the tactile duration aftereffect, which is dependent on the topographic distance between fingers

2.2. EEG results

The tactile test stimulus evoked clearly identifiable C waves both in the fronto-central and contralateral scalps ig moreover, we observed a clear L C after the offset of the test stimulus in the fronto-central scalp therefore, further statistical analyses were focused on the C amplitudes in the fronto-central and contralateral scalps, and L C amplitude in the fronto-central scalp global field power was used to identify measurement windows ig this was calculated as the standard

deviation of the electrical potential of all electrodes at each time point, resulting in a single value at each time sample Lehmann and Landis, Murray et al., and has been used previously to identify the E wave's time window during temporal perception g et al., Jener et al., using the E from the data for all trials, a "late" E response was identified after the onset of the tactile test stimulus, which encompassed the C in the fronto-central and contralateral scalps ig B and the peak of activity around $100-150$ ms after the offset of the tactile test stimulus was also identified this time window encompassed an L C in the fronto-central scalp ig B Correspondingly, the C amplitude was defined as the mean voltage in the $100-150$ ms time segment after the onset of the tactile test stimulus in the fronto-central and contralateral scalps the L C amplitude was quantified as the mean voltage in a $100-150$ ms window ± 50 ms around the peak of the L C , which was defined as the maximum value in the $100-150$ ms time segment after the offset of the tactile test stimulus in the fronto-central scalp similarly to the behavioral results, s of the C or L C were defined as the arithmetic difference between C or L C amplitudes in each adaptation condition and in the no adaptation condition

2.2.1. CNV

The duration adaptation effect on the subsequent tactile duration perception in the C wave was examined using a scalp location fronto-central, contralateral \times adapting duration short, long \times adapting location consistent, adjacent, homologous repeated measures this yielded a significant main effect of the adapting location $F(2, 34) = 4.1, p = .02, \eta^2 = .34$, and a significant scalp location \times adapting duration interaction $F(2, 34) = 3.1, p = .05, \eta^2 = .30$ moreover, a significant scalp location \times adapting duration \times adapting location interaction $F(2, 34) = 4.1, p = .02, \eta^2 = .34$ as also observed to dissect these interactions, separate adapting duration short, long \times adapting location consistent, adjacent, homologous repeated measures s were conducted for each scalp location

In the fronto-central scalp ig , left column, a significant main effect of the adapting location was found $F(2, 34) = 4.1, p = .02, \eta^2 = .34$, while no other main effect and interaction were significant both $ps > .05$ ig Bonferroni post hoc analyses revealed that

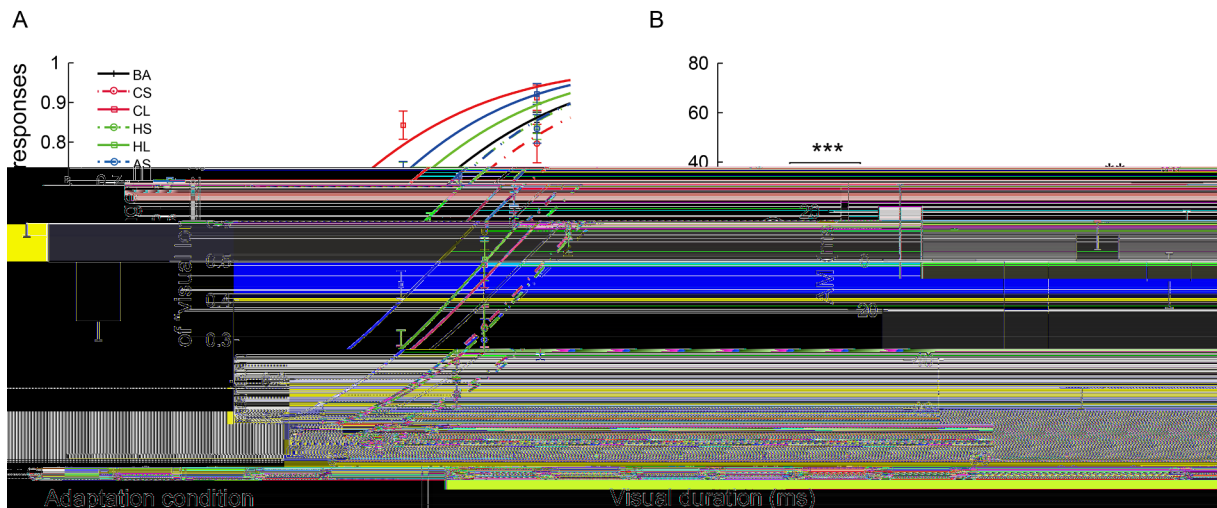


Fig. 2. Results of the behavioral analysis psychometric functions averaged across eighteen participants showing the proportion of "longer" responses to the visual reference stimuli, which was fitted with a binomial logit function of the visual reference duration in each condition B baseline, no adaptation C, adapt to a short duration on the consistent, homologous, and adjacent fingers, respectively CL, L, L adapt to a long duration on the consistent, homologous, and adjacent fingers, respectively B s of the E were calculated as the arithmetic difference between E s in each adaptation condition and in the no adaptation condition Error bars represent standard errors in each condition $^{***} p < .001, ^{**} p < .01$

the α in the consistent condition was significantly smaller than that in the adjacent condition ($p = 0.001$, Cohen's $d = -0.35$), and was marginally significantly smaller than that in the homologous condition ($p = 0.05$, Cohen's $d = -0.25$), whereas there was no significant difference between homologous and adjacent conditions ($p = 0.15$, Cohen's $d = -0.15$). Based on visual inspection of averaged waveforms, the selected α windows were found to mainly include the descending part of the C wave. The C wave amplitude defined as the mean voltage in the 100–150 ms time segment was thus reanalyzed, but without any change in the results. These results suggest that it is the adapting location, but not the adapting duration, that affects C wave amplitude in

interaction $F(1, 16) = 3.8, p = .06, \eta^2 = .19$ were found to be marginally significant. Simple effect analysis showed that the μ in the C condition was significantly larger than that in the CL condition ($p = .01, Cohen's d = .45$), and the μ in the L condition was significantly larger than that in the CL condition ($p = .001, Cohen's d = .71$), while there was no difference between C and L conditions ($p = .12, Cohen's d = .16$). The peak latency of the L C was also analyzed. However, no main effects or interaction were found to be significant. All $ps > .05$. These analyses suggest that the L C amplitude in the fronto-central scalp is modulated by the tactile duration adaptation, which is dependent on the topographic distance between the adapting and test fingers. However, we did not find any significant correlations between the behavioral and the L C. The arithmetic difference between L C amplitudes in "adapting short" and "adapting long" conditions at individual level in different adapting location conditions, separately, all $ps > .05$. **Fig. 3** B. It suggests that the L C cannot directly predict the behavioral duration aftereffect.

3. Discussion

The present study investigated the effect of tactile duration adaptation on EE correlates of subvent tactile duration perception, yielding a number of findings. First, the tactile duration adaptation induced a significant tactile duration aftereffect when the adapting and test fingers were consistent or adjacent, but not homologous. Second, the tactile duration adaptation has effects on subvent EEs. The C and L C amplitudes were found to be strongly modulated by the duration adaptation. Critically, these adaptation effects were dependent on the adapting location. This study hence revealed a coherent behavioral electrophysiological link for the somatotopically organized tactile duration aftereffect.

Consistent with our previous study [Li et al., 2019](#), behavioral results provided further evidence that the effect size of the tactile duration aftereffect is contingent on the topographic distance between fingers. Specifically, the aftereffect could transfer to adjacent fingers even when the frequency of the tactile stimulus was relatively low, i.e., [Fig. 3](#) B, but not homologous fingers. Moreover, it

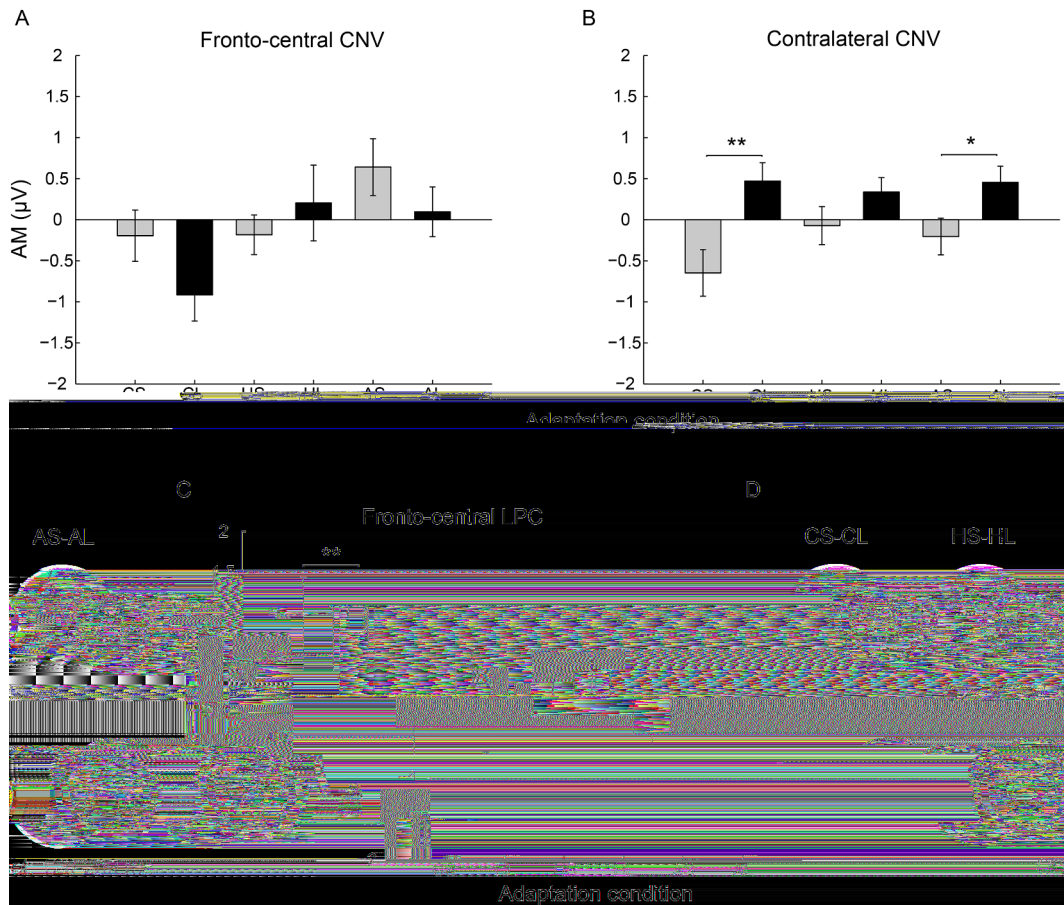


Fig. 5. ERP components, and difference maps for the measurement conditions in different conditions (C, L, HS, HL, AL) adapt to a short duration on the consistent, homologous, and adjacent fingers, respectively (CL, HL, AL) adapt to a long duration on the consistent, homologous, and adjacent fingers, respectively. A: AM of the CNV in the fronto-central scalp. B: AM of the CNV in the contralateral scalp. C: AM of the LPC in the fronto-central scalp. D: The difference maps “adapting short” – “adapting long” for C and L C components. The left of each map is ipsilateral scalp; the right of each map is contralateral scalp. Error bars represent standard errors in each condition. $p < 0.05$, $p < 0.01$.

behavioral responses as significantly larger in the consistent condition than in the adjacent and homologous conditions (both $p < 0.05$, Cohen's $d > 0.2$). Here, as a marginally significant difference for behavioral responses between adjacent and homologous conditions ($p = 0.06$, Cohen's $d = 0.1$), this result further suggests that the transfer of the tactile duration aftereffect between adjacent fingers is only partial, not full. Our previous study has demonstrated that the duration aftereffect is contingent on the low-level auditory feature (i.e., auditory frequency) but not on the low-level visual feature (i.e., visual orientation) (Li et al., 2019). This suggests the duration adaptation in the auditory modality may arise at a relatively earlier stage of sensory processing than that in the visual modality. Here, similar to the auditory duration aftereffect, the tactile duration aftereffect is dependent on the topographic distance between fingers. This is consistent with the characteristics of early stages of tactile processing (Burton and Inclair, 2019), and suggests an early duration adaptation mechanism in the somatosensory system. The early adaptation mechanism is also consistent with previous studies on the frequency adaptation (Urai et al., 2015) or, for example, the temporal compression aftereffect, resulting from adaptation to dynamic stimuli (e.g., visual motion or flicker, tactile utterance), has been found in the visual and tactile modalities (Johnston et al., 2019; Atanabe et al., 2020). This aftereffect is spatially specific, and limited to relatively high temporal frequencies, which suggests the pre-cortical processing of duration (Yhan et al., 2019; Bruno et al., 2019; Johnston et al., 2019; Atanabe et al., 2020). Moreover, the tactile duration aftereffect observed here partially transferred to the adjacent fingers, and was independent of the frequency of the tactile stimulus (see the supplement,

Fig. B). These results suggest the tactile duration aftereffect should not result from the adaptation of tactile response channels (mechanoreceptive afferents), and imply a cortical processing of duration in the somatosensory cortex. To further uncover how the tactile duration adaptation modulates subsequent perception of tactile duration, this study focused on the C component, which is elicited by the onset of the tactile test stimulus – the point at which temporal encoding is engaged – and also on the L C component, which is elicited by the offset of the tactile test stimulus during the temporal memory stage. Adaptation to the shorter tactile duration was found to increase the C component amplitude in the contralateral scalp, whereas adaptation to the longer tactile duration decreased it. Similar modulation was observed in the L C amplitude in the fronto-central scalp. Importantly, those modulations took place only when the adapting and test stimuli were presented on consistent or adjacent fingers, but not homologous fingers. These ERP results match well with the observations from behavioral results. Previous studies have suggested that the C component amplitude reflects the neural correlates of temporal encoding (Acar et al., 2019; Jänner et al., 2019). These C component results suggest that the tactile duration adaptation modulates subsequent temporal encoding. It is also consistent with a previous study on the visual duration aftereffect (Li et al., 2019). In addition, the L C component observed here was similar to the component observed in the central scalp at the offset of the comparison interval for a short interval, as reported by Arantino et al. (2019). It has been suggested that the L C component is related to working memory processes. Accordingly, these results further indicate that the later temporal processing mechanism (i.e., temporal memory) is also involved in the tactile duration aftereffect.

Previous studies demonstrated that the C is typically found over the fronto central scalp during explicit temporal processing (Kononov, Icz and Anin, Li et al., Iener et al., In this study, Cs were observed not only in the fronto central scalp, but also in the contralateral scalp. This is consistent with a previous finding that showed the C is widespread across the scalp (Feuty et al.,). Moreover, this study found that only the C in the contralateral scalp is sensitive to the duration adaptation effect. This dissociated pattern suggests that Cs in the fronto central and contralateral scalps might reflect different temporal processes, such as accommodating to specific tasks such as explicit vs implicit timing. Indeed, a recent study found that the time interval adaptation has no effect on the C amplitude in the fronto central scalp when participants were asked to complete an implicit timing task (Aya et al.,). In addition, Raamstra et al. investigated the neurophysiology of implicit timing and found that C manifestations of implicit timing originate in the lateral instead of the medial premotor cortex.

The adaptation effect on the C in the contralateral scalp is consistent with the inference of the behavioral result, which suggests the early somatosensory areas play an essential role in the sub-second tactile duration perception. This is in line with previous studies, which suggest the primary somatosensory cortex is involved in tactile temporal processing (Conte et al.,occhi et al.,). According to the duration channel based model, our brain contains duration tuned neurons, each of which responds selectively to a narrow range of stimulus durations centered on its preferred duration (Eron et al.,). Consistent with this idea, duration tuned neurons have been found in the visual and auditory nervous systems in specific animal species (Casseday et al.,uyens et al.,aure et al.,). Recent fMRI studies also showed that such duration selective neurons exist in the human right parietal cortex, in which the neuron adaptation is related to the visual duration aftereffect (Ayashi et al.,ayashi and ry,). Combined with the present results, it is possible that the duration tuned neurons also exist in the somatosensory system. Moreover, little evidence has suggested the direct relation between the response of duration tuned neurons and the C activity. Instead, it has suggested that the C could be driven by a climbing neural activity process (Feuty et al.,eutmänn et al.,). Therefore, the C in the contralateral scalp might not directly reflect the overall activity of duration tuned neurons in the early somatosensory areas. Instead, it is possible that other neurons which receive the signals from the duration tuned neurons may generate the C.

There is an ongoing debate on the perceptual and cognitive functions underlying the E component of C (Kononov, Icz and Enney, Anin et al.,). Previous studies have focused on C activity during a temporal comparison task, in which participants compared a current duration to a memorized duration and then prepared a motor response (Acar and Vidal, g et al., feuty et al.,). As such, the C evoked during temporal comparison may reflect multiple cognitive processes, including memory encoding and subsequence decision making. In the present study, the tactile test stimulus was always presented before the visual reference stimulus. This made it possible to investigate the adaptation effect on the subsequence C evoked by the onset of the tactile test stimulus, largely free from memory, motor preparation, and decision processes. Moreover, this manipulation also helped to distinguish the L C evoked by the offset of the tactile test stimulus from the L C related to decision making that was observed in previous studies (Aul et al.,). Moreover, it should be noted that presenting the tactile test stimulus before the visual reference stimulus also simplified the duration discrimination task. In this situation, participants may pay more attention to the visual reference with variable durations, and timing for the tactile test stimulus could be more implicit. Moreover, some extent, this design could explain why the duration adaptation effect on the C amplitude in the fronto central scalp was not observed.

In the present study, the adaptation effect on typical somatosensory components (e.g., , , , , d) was not examined. Identical numbers of adapting stimuli were used in all adaptation tests, and this means that the total period of the tactile adaptation was different between "adapting long" and "adapting short" conditions. It has been suggested that the tactile adaptation itself could affect these earlier somatosensory components (Bradley et al.,). Therefore, it was not possible to strictly distinguish the effects of the duration adaptation vs the tactile adaptation on these components. Nevertheless, this does not mean that the tactile duration adaptation has no effect on these components. An important avenue for future research could be to examine the duration adaptation effect on these earlier somatosensory components by controlling the total duration of adapting stimuli (e.g., adapting to the unfiltered interval mediated by too brief tactile stimuli). Accordingly, one may question whether the effects of the duration adaptation on the C and L C amplitudes were merely the result of the total period of adaptation. We found that the of the C in the contralateral scalp and the of the L C in the fronto central scalp were dependent on the duration of the adapting stimulus, but not on the tactile adaptation itself. This is not consistent with the hypothesis that the tactile adaptation itself could modulate subsequence C and L C amplitudes. To further rule out this possibility, a supplementary analysis was conducted, in which the E vs between no adaptation and adaptation conditions were compared regardless of adapting durations. Interestingly, the results showed that there was no significant difference for either C or L C amplitudes between the adaptation and no adaptation conditions (both $p >$). Thus, it was the tactile duration adaptation, and not merely the tactile adaptation, that modulated subsequence C and L C amplitudes.

Although we found significant effects of the tactile duration adaptation on C and L C amplitudes, the changes of the t to E components cannot directly predict the behavioral duration aftereffect at individual level. The underlying reasons may be complicated. One possibility is that the duration judgement in the present duration discrimination task was determined not only by the tactile test stimulus, but also by the subsequence visual reference stimulus. Thus, the temporal processing for the tactile stimulus alone could not predict the overall outcome of the duration judgement.

In sum, the present study used EEG to investigate how the tactile duration adaptation affects subsequence tactile duration perception. It provides further evidence that the tactile duration adaptation results in the tactile duration aftereffect, which is organized within a somatotopic framework. Moreover, this adaptation effect is manifested in the C and L C amplitudes, which are respectively associated with temporal encoding and memory processes. In the information processing perspective, this indicates that the tactile duration adaptation not only modulates subsequence temporal encoding, but also modulates subsequence temporal memory. The present study helps us to understand the neural underpinnings of the tactile duration aftereffect.

4. Experimental procedures

4.1. Participants

Twenty healthy participants were recruited. All participants reported normal or corrected to normal vision and normal tactile sensations and had no history of neurological diseases. They were naive to the purpose of the experiment. They gave written informed consent and were paid for their time. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the human subject review committee of Beijing Normal University. Data from four participants were discarded, due to their poor performance in the duration discrimination task or excessive artifacts in the EEG data. The final sample was composed of eighteen participants (females mean age \pm years).

4.2. Apparatus and stimuli

Participants were comfortably seated in a chair in a dim, sound attenuated, and temperature controlled room. The visual stimulus was a white disc 10° in diameter, which was presented on the center of a 24" CRT monitor with a refresh rate of 60 Hz. The background was a gray background. The tactile stimulus was a sine wave vibration characterized by a 100 ms cosine on and off ramp. The vibration was delivered to a round aluminum probe 2 mm in diameter by a piezo tactile stimulator (Vibratron, Telford, Yorkshire, England), which was connected to a digital to analog conversion sound card. The probe was located in a hole 2 mm in diameter in one end of a rectangular machined ceramic case. During the experiment, participants placed their fingers against the cases and touched the flat surfaces of the probes with their fingertips. Finger rests were used to fix the contact position between the finger and the probe. Participants wore headphones with continuously presented pink noise and earplugs to maximally shield the noise from the vibrating stimulator. Participants' hands were covered by an opaque towel and hence invisible throughout the experiment. Stimulus presentation and behavioral data collection were implemented with Matlab (Mathworks) and psychophysics toolbox (Brainard, 2003;elli, 2005).

4.3. Procedure

During the experiment, participants completed experimental tasks with eight blocks: two no adaptation blocks and six adaptation blocks. In each no adaptation block, participants put their hands with palm down on the supporting desk and kept their eyes on the center of the screen. During each trial, a test and a reference were presented successively with an inter-stimulus interval of 1000 ms. The test was a 100 ms tactile stimulus presented on the index fingertip of the left or right hand, counterbalanced across participants. Hand index that our pilot experiment showed that the tactile duration aftereffect did not transfer to the visual modality (see the supplement, elli, 2005). We used the visual stimulus as the reference, whose duration was one of the durations: 100 ms, 200 ms, 300 ms, 400 ms, 500 ms. These reference durations were presented randomly but counterbalanced upon the disappearance of the reference, participants made an unspeeded, two-alternative forced choice (2AFC) to determine which stimulus tactile or visual lasted longer. Participants pressed the left or right mouse button with their thumbs to indicate their responses. The button press was counterbalanced across participants: half the participants pressed the left button for "tactile longer" and the right button for "visual longer", while the other half responded with the reversed mapping. There were trials in each no adaptation block, with trials for each reference duration.

Each adaptation block included two phases: adaptation and test. During the adaptation phase, an adapting tactile stimulus with a brief duration of 100 ms was repeatedly presented 10 times, with an interval of 1000 ms. After this initial adaptation phase, a test phase followed. The test phase was similar to the no adaptation block, except that four top-up stimuli, which were identical to those presented in the preceding adaptation phase, were presented before each test stimulus. The interval between the last top-up stimulus and the test was 1000 ms.

The different combinations of fingers and durations used in the adaptation phase resulted in six adaptation blocks: "adapt to a short duration on the consistent finger (C)", "adapt to a long duration on the consistent finger (CL)", "adapt to a short duration on the homologous finger (H)", "adapt to a long duration on the homologous finger (HL)", "adapt to a short duration on the adjacent finger (A)", and "adapt to a long duration on the adjacent finger (AL)". The test stimulus (as presented on the index finger of the left or right hand, and thus the "consistent", "homologous" and "adjacent" fingers respectively) referred to the index finger of the left or right hand, the index finger of the right

or left hand, and the middle finger of the left or right hand. In homologous and adjacent conditions, the physical distance between the adapting and test fingertips was about 2 cm. In the experiment, the order of adaptation blocks was random. In no adaptation blocks, the test was presented before and after the adaptation blocks, respectively after each block, and participants took a break of at least 10 minutes to wash out any potential carry-over effect between blocks.

ranging from \sim to ms relative to the offset of the tactile test stimulus with a baseline of the ms interval preceding the offset. Here, we focused on the fronto-central and parieto-central electrode sites, where the C or the post-stimulus components were usually reported to be maximal (Acar and Vidal, Parantino et al., 2020). Herein, given that our previous study has suggested somatosensory areas play an essential role in the tactile time processing (Li et al., 2020), electrodes over the somatosensory cortex were also demonstrated to increase the signal-to-noise ratio. Electrodes were analyzed by pooling four neighboring electrodes within four regions of interest on a scalp level: scalp sites of our cohorts of scalp sites were distributed in the fronto-central scalp (Cz, C, Cz, C), parieto-central scalp (Z, Z, C, Z), and contralateral/ipsilateral scalps (C, C, C, C).

CRedit authorship contribution statement

Baolin Li: Conceptualization, methodology, investigation, formal analysis, writing original draft, writing review & editing. **Jianrong Jia:** methodology, investigation, writing review & editing. **Lihan Chen:** Conceptualization, methodology, writing original draft, writing review & editing. **Fang Fang:** Conceptualization, methodology, writing review & editing, supervision, project administration, funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.brainres.2021.147432>.

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