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Localizing somatic symptoms associated with childhood maltreatment

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Childhood maltreatment has been linked to adult somatic symptoms, although this has rarely been examined in daily life. Furthermore, the localization of somatization associated with childhood maltreatment and its subtypes is unknown. This large-scale experience sampling study used body maps to examine the relationships between childhood maltreatment, its subtypes, and the intensity and location of negative somatic sensations in daily life. Participants (N = 2,234; 33% female and 67% male) were part of MyBPLab 2.0, a study conducted using a bespoke mobile phone application. Four categories of childhood maltreatment (emotional abuse, emotional neglect, physical abuse, and physical neglect) were measured using the Childhood Trauma Questionnaire. Using gender-matched human silhouettes, participants indicated the location and intensity of feelings of negative activation in the body. Childhood maltreatment generally and its four measured subtypes were all positively associated with heightened negative activation on both the front and back body maps. For females, total childhood maltreatment was associated with negative activation in the abdomen and lower back, while for males, the association was localized to the lower back. Similarly, each of the four subscales had localized associations with negative activation in the abdomen and lower back in females and lower back in males, except for emotional abuse, which was also associated with negative activation in the abdomen in males. These associations likely reflect increased somatization in individuals exposed to childhood maltreatment, suggesting a role for psychotherapeutic interventions in alleviating associated distress.

childhood maltreatment | adverse childhood experiences | somatization | body maps | experience sampling

Significance

Childhood maltreatment has been linked to physical symptoms in adulthood, but where symptoms manifest in the body is not well understood. In a study using a mobile app, over 2,000 participants reported on their experiences of childhood maltreatment and indicated on a body silhouette where they were feeling negative activation, such as a pounding in the head. Greater childhood maltreatment was linked with greater negative activation in the body. For females, this relationship was found specifically in the abdomen and lower back. For males, it was found specifically in the lower back, except that the association with emotional abuse also localized to the abdomen. These unpleasant sensations might be primarily of psychosomatic origin, highlighting the possible utility of psychosocial interventions.

Childhood maltreatment, defined as abuse or neglect before the age of 18, is a pervasive global issue. Meta-analytic studies estimate worldwide prevalence rates of 22.6% for physical abuse, 16.3% for physical neglect, 36.3% for emotional abuse, and 18.4% for emotional neglect, with no differences between genders (1–3). For sexual abuse, gender differences exist, with prevalence rates of 18.0% for girls and 7.6% for boys (4).

Somatic symptoms are sensations that are localized to some part of the body and are experienced as unpleasant or worrisome (5). They may either be the result of pathology in the affected region or they may have no medical basis. In the latter case, where medical explanations are deemed unlikely, somatic sensations may be described as psychosomatic in origin or, equivalently, as reflecting somatization (6). Regardless of their cause, the presence of somatic symptoms can result in significant anguish, but somatic symptoms that are the result of somatization are also burdensome in other ways (7, 8). For example, they can result in medical overinvestigation and unnecessary procedures, with resulting stress, discomfort, and risk. Additionally, uncertainty regarding the cause of somatic symptoms can be highly distressing.

A large body of evidence now demonstrates that childhood maltreatment is associated with somatic symptoms in adulthood (6, 7, 9–18). For example, meta-analytic evidence has shown that childhood maltreatment is associated with higher scores on medical symptom checklists, but also with more frequent diagnoses of a large range of disorders, including musculoskeletal and gastrointestinal disorders (9). In another set of meta-analyses, not only did individuals who experienced childhood maltreatment have higher rates of chronic pain in adulthood, but in separate samples of adults with chronic pain, childhood maltreatment was overrepresented (10). Although most evidence linking childhood maltreatment and somatic symptoms does not distinguish between symptoms due to medical illness and those due to somatization, some research has specifically shown an association with putatively psychosomatic symptomatology. For example, in data from a population-based cohort study, sexual abuse was associated with higher odds of having a somatoform disorder, as diagnosed using a standardized, structured interview and Diagnostic and Statistical Manual IV criteria (12). In another report, among people with fibromyalgia, which affects over 200 million people worldwide (19), and for which there is no identifiable

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medical cause in individual patients, 64.7% of individuals had a background of childhood maltreatment (20). Clearly, understanding and mitigating the impact of childhood trauma on somatic symptoms is a pressing public health priority.

However, there are notable gaps in the current literature. First, the prevailing assessment method of somatic symptoms has limitations. Most studies have assessed somatic symptoms through retrospective self-report via conventional questionnaires, asking respondents to recall past symptoms over extended periods, which can introduce recall bias. Ecological momentary assessment is an alternative approach that minimizes this bias by capturing individuals' experiences in real time and in their natural environments (21, 22). Another widespread methodological limitation is that many studies rely on preset lists of somatic symptoms. Such lists might not encompass the unique physical manifestations that an individual might experience.

Second, the type of childhood maltreatment is often not examined. The bulk of the research on the consequences of childhood maltreatment with respect to somatic symptoms has focused specifically on childhood sexual abuse in female participants. While some research has identified connections between specific maltreatment subtypes and adult somatic symptoms, the results remain inconsistent. For instance, one comparative study linked somatic symptoms to emotional and sexual abuse (7), while another linked them to emotional abuse and physical neglect (12).

Third, research examining the localization of somatic symptoms within the body has been scarce. One relevant study examined the relationship between childhood abuse and the location of somatic symptoms in various body regions such as the head, chest, abdomen, and throat (16). Conducted using 85 female internal medicine patients, this study analyzed localized somatic symptoms using regression models that simultaneously included multiple abuse domains. Results were nonsignificant and challenging to interpret. Research on embodied emotions has utilized body mapping technology to pinpoint the localization of emotions in the body (23). This method has been employed in the general population (24), in individuals with conditions like schizophrenia (25) or major depressive disorder (26), in relation to antisocial and impulsive personality traits (27), and in the context of childhood maltreatment (28). Applying this method to pinpoint the localization of somatization associated with childhood maltreatment could be consequential. Understanding where somatic symptoms are located in the body after childhood maltreatment can inform intervention strategies and help dispel the stigma surrounding these symptoms. Additionally, information on localization may provide insight into the likely mechanisms of the association between childhood maltreatment and somatization.

To address these gaps in the literature, we leveraged a large-scale experience sampling study called MyBPLab (29), involving over 2,000 male and female participants. We aimed to investigate the impact of childhood maltreatment (both in general and for each of four subtypes: emotional abuse, emotional neglect, physical abuse, and physical neglect) on the intensity and location of unpleasant somatic sensations in daily life, using body maps for precise localization. Drawing from the existing literature, we hypothesized that greater exposure to childhood maltreatment is associated with increased reported negative activation in the body. Additionally, we explored whether certain subtypes of childhood maltreatment are associated with heightened bodily negative activation. Finally, we explored whether childhood maltreatment and its subtypes are associated with negative activation in specific locations in the body.

Results

Childhood Maltreatment and Negative Activation in the Body. Analyses were run involving the prediction of the intensity of negative activation in the body generally, as measured by the total touch count across each body map (i.e., front and back), from childhood trauma questionnaire (CTQ) total score and covariates. Results are presented in Fig. 1, *Left*, and Table 1. For both the front and back body maps, greater maltreatment exposure was associated with a higher touch count. Age was also a significant predictor of total touch count, with increasing age being associated with fewer touches on both the front and back body maps. Gender was also associated with touch count, with females having 1.21 (95% CI: 1.15 to 1.27) fold more touches than males on the front body maps and 1.23 (95% CI: 1.18 to 1.29) fold more touches than males on the back body maps. Neither race nor education was associated with total touch count.

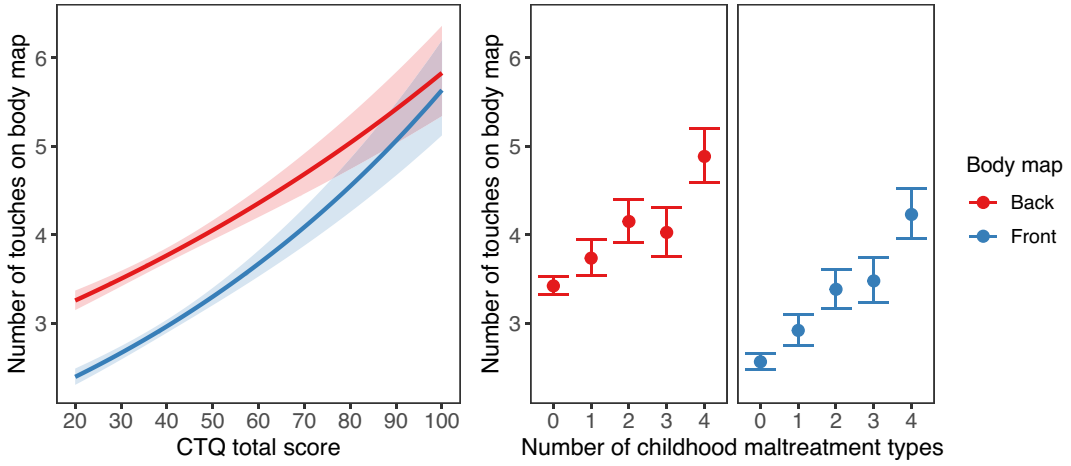

Fig. 1. Extent of childhood maltreatment as a predictor of negative activation in the body. Using a touchscreen, participants were able to touch on a body map to indicate "negative activation, such as a pounding in the back of your head." *Left:* Childhood maltreatment (measured using the CTQ total score) was positively associated with reported negative activation on both the front and back of the body. *Right:* The number of maltreatment subtypes (i.e., physical abuse, physical neglect, emotional abuse, emotional neglect) for which a participant's score reflected at least moderate maltreatment was associated with touch count for both the front and back body maps. Values are adjusted for age and gender, i.e., they represent model-estimated marginal means ± 95% CIs.

Table 1. Association between total touch count and CTQ total score and covariates

Body map	Model term	Df	F	*P*	Partial correlation	Fold change per SD
Front	CTQ total score	1	44.4	<0.001	0.14 (0.10 to 0.18)	1.17 (1.14 to 1.20)
	Age	1	79.3	<0.001	−0.19 (−0.23 to −0.15)	0.79 (0.77 to 0.81)
	Gender	1	12.6	<0.001		
	Race	5	0.9	0.51		
	Education	5	1.2	0.31		
	Residuals	2,196				
Back	CTQ total score	1	22.7	<0.001	0.10 (0.06 to 0.14)	1.11 (1.09 to 1.14)
	Age	1	90.0	<0.001	−0.20 (−0.24 to −0.16)	0.79 (0.78 to 0.81)
	Gender	1	18.0	<0.001		
	Race	5	0.9	0.48		
	Education	5	0.9	0.47		
	Residuals	2,196				

Two models were fit: one for the front body map data and one for the back body map data. Degrees of freedom (Df), F statistics, and *P*-values are presented for all terms in each model. For continuous variables only, partial correlations and fold change per one SD of the predictor are presented. Values in parentheses represent the 95% CI.

Several sensitivity analyses were performed. Three sets of models were run with an additional covariate, specifically affective valence (*SI Appendix*, Table S1), affective arousal (*SI Appendix*, Table S2), or tendency to underreport maltreatment, as measured by the CTQ minimization/denial score (*SI Appendix*, Table S3). Covarying for these predictors did not meaningfully change the effect size or statistical significance for the CTQ total score, suggesting that these constructs did not represent mediators or confounders of the observed association between childhood maltreatment and body map touch count. Of these constructs, only affective valence was significantly related to touch count, with a more negative affect being associated with a higher touch count. A final set of models did not exclude participants who only touched on either the front or back body map. In these analyses, the effect size point estimates, effect size CIs, and significance levels for CTQ total score were unchanged to two decimal places (*SI Appendix*, Table S4).

Additional analyses looked at whether the number of different types of childhood maltreatment experienced was associated with total touch count. Results are presented in Fig. 1, *Right*. The number of subscales where the participant's score reflected at least moderate maltreatment was associated with touch count for both the front ($F_{4,\ 2220} = 11.7$, $P < 0.001$) and back ($F_{4,\ 2220} = 6.2$, $P < 0.001$) body maps. For the front body map, post hoc testing revealed that individuals who experienced at least moderate maltreatment on one ($P = 0.003$), two ($P < 0.001$), three ($P < 0.001$), or four ($P < 0.001$) subscales all had higher touch counts than those who did not experience at least moderate maltreatment on any subscale. Similarly, for the back body map, individuals reporting at least moderate maltreatment on one ($P = 0.04$), two ($P < 0.001$), three ($P < 0.001$), or four ($P < 0.001$) subscales all had higher touch counts than those who did not report moderate maltreatment on any subscale.

Childhood Maltreatment Subtypes and Negative Activation in the Body. The association between each of the four CTQ subscales and intensity of negative activation in the body generally was assessed, covarying age and gender, and the results are presented in Table 2. Separate models were fit for each CTQ subscale. All four subscales were positively associated with total touch count on both the front and back body maps.

Additional analyses were conducted to examine whether each CTQ subscale was uniquely associated with body map touch count. Specifically, lasso Poisson regressions were conducted in which all four CTQ subscales were included simultaneously as predictors, along with age and sex. Lasso regression addresses multicollinearity in part by shrinking model coefficients. For the front body map, the only predictors in the model with nonzero coefficients were age (0.94 fold change per SD) and the CTQ emotional abuse score (1.10 fold change per SD). For the back body maps, only age (0.89 fold change per SD), sex (1.01 fold higher in females), and CTQ emotional abuse score (1.08 fold change per SD) were retained.

Locations of Associations between Childhood Maltreatment and Negative Activation in the Body. The average number of touches per person is presented for each pixel in Fig. 2, *Upper row*. Average patterns of negative activation were similar for males and females.

Table 2. Association between total touch count and CTQ subscales

Body map	CTQ subscale	F	*P*	Partial correlation	Fold change per SD
Front	Emotional abuse	67.3	<0.001	0.17 (0.13 to 0.21)	1.21 (1.19 to 1.24)
	Physical abuse	33.8	<0.001	0.12 (0.08 to 0.16)	1.14 (1.12 to 1.16)
	Physical neglect	23.8	<0.001	0.10 (0.06 to 0.14)	1.12 (1.10 to 1.15)
	Emotional neglect	18.0	<0.001	0.09 (0.05 to 0.13)	1.11 (1.08 to 1.14)
Back	Emotional abuse	39.2	<0.001	0.13 (0.09 to 0.17)	1.15 (1.13 to 1.17)
	Physical abuse	21.5	<0.001	0.10 (0.06 to 0.14)	1.10 (1.08 to 1.12)
	Physical neglect	9.9	0.002	0.07 (0.02 to 0.11)	1.07 (1.05 to 1.09)
	Emotional neglect	7.4	0.007	0.06 (0.02 to 0.10)	1.06 (1.04 to 1.09)

For each body map, CTQ subscales are sorted by effect size. Eight models were fit: four for the front body map data and four for the back body map data. Each model included the score for one CTQ subscale along with gender and age. F statistics, *P*-values, partial correlations, and fold change per one SD of the CTQ subscale are presented. Values in parentheses represent the 95% CI. Numerator degrees of freedom was always 1, and denominator degrees of freedom were between 2226 and 2229.

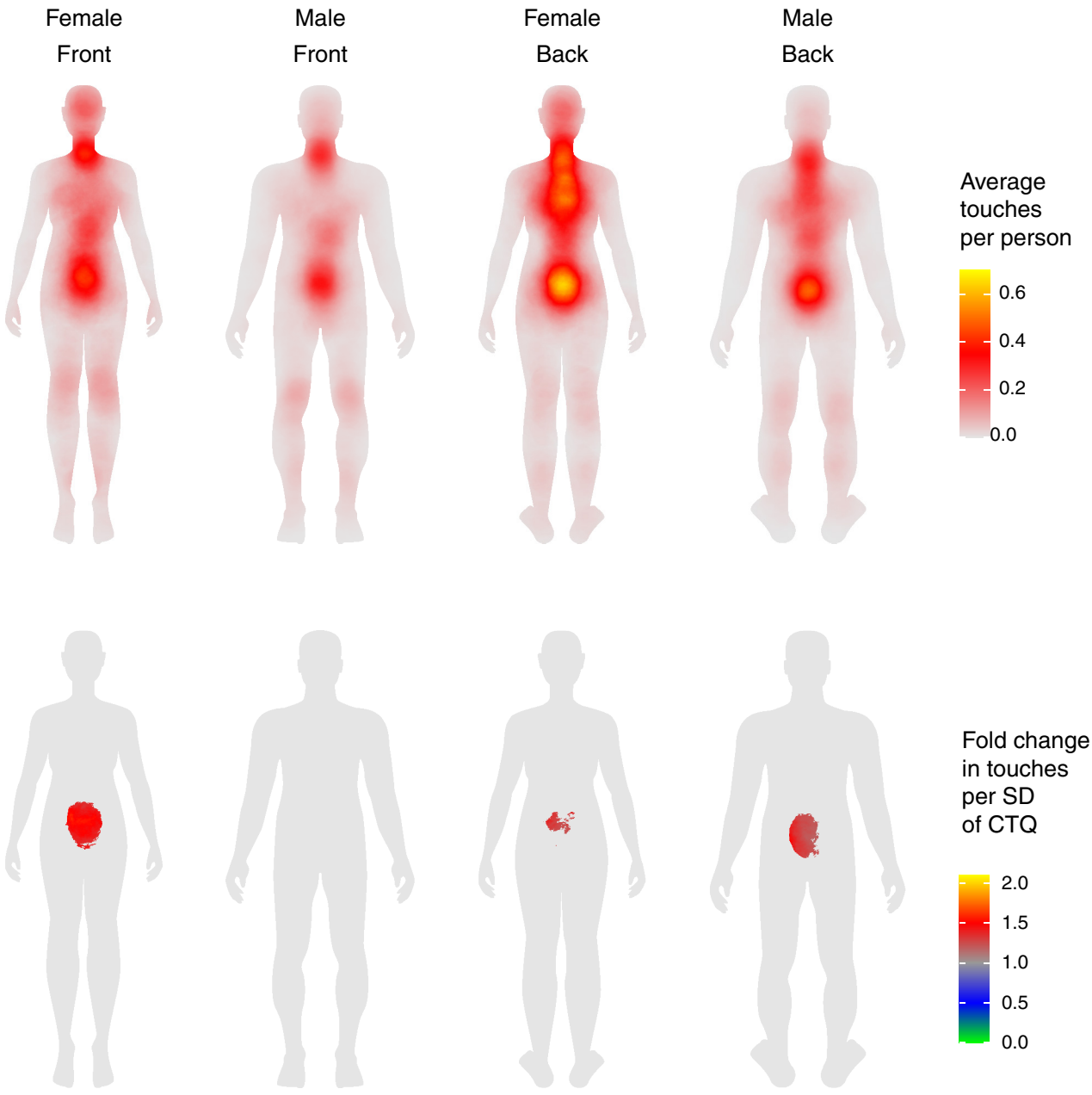

Fig. 2. Locations of negative activation in general and of negative activation associated with childhood maltreatment. *Upper row*: When presented with the front body maps, female and male participants reported the most negative activation in the abdomen and neck. Using the back body maps, female and male participants reported the most negative activation in the lower back, followed by the neck and upper back. *Lower row*: Childhood maltreatment as measured using the CTQ total score was positively associated with negative activation in all maps except the male front map. The strongest association with negative activation was observed for the abdomen in female participants, but significant associations were also observed for the lower back in both female and male participants. SD: standard deviation.

On the front body maps, touches were largely localized to the abdomen and neck. On the back body maps, touches were mostly localized to the lower back, upper back, and neck.

Childhood maltreatment, as measured by the CTQ total score, showed a localized association with negative activation in the body in the front and back body maps for females and the back body map but not the front body map for males (Fig. 2, *Lower row*). Specifically, childhood maltreatment was associated with negative activation in the abdomen and lower back for females, and the lower back for males. Although effect sizes are presented only for statistically significant pixels, effect sizes in regions that were not statistically significant were generally close to null, including in regions with high average touch counts. This suggests that the observed associations were truly localized to the identified areas, rather than localization being an artifact of increased statistical power.

Locations of Associations between Childhood Maltreatment Subtypes and Negative Activation in the Body. Each of the four CTQ subscales was examined as a predictor of localized negative activation in the body (Fig. 3). Emotional abuse had the largest number of localized associations with negative activation, showing associations across all four body maps, including an association in males with negative activation in the abdomen that was not observed with the CTQ total score. The emotional neglect, physical abuse, and physical neglect subscales had localized associations with negative activation that predominantly occurred in the same

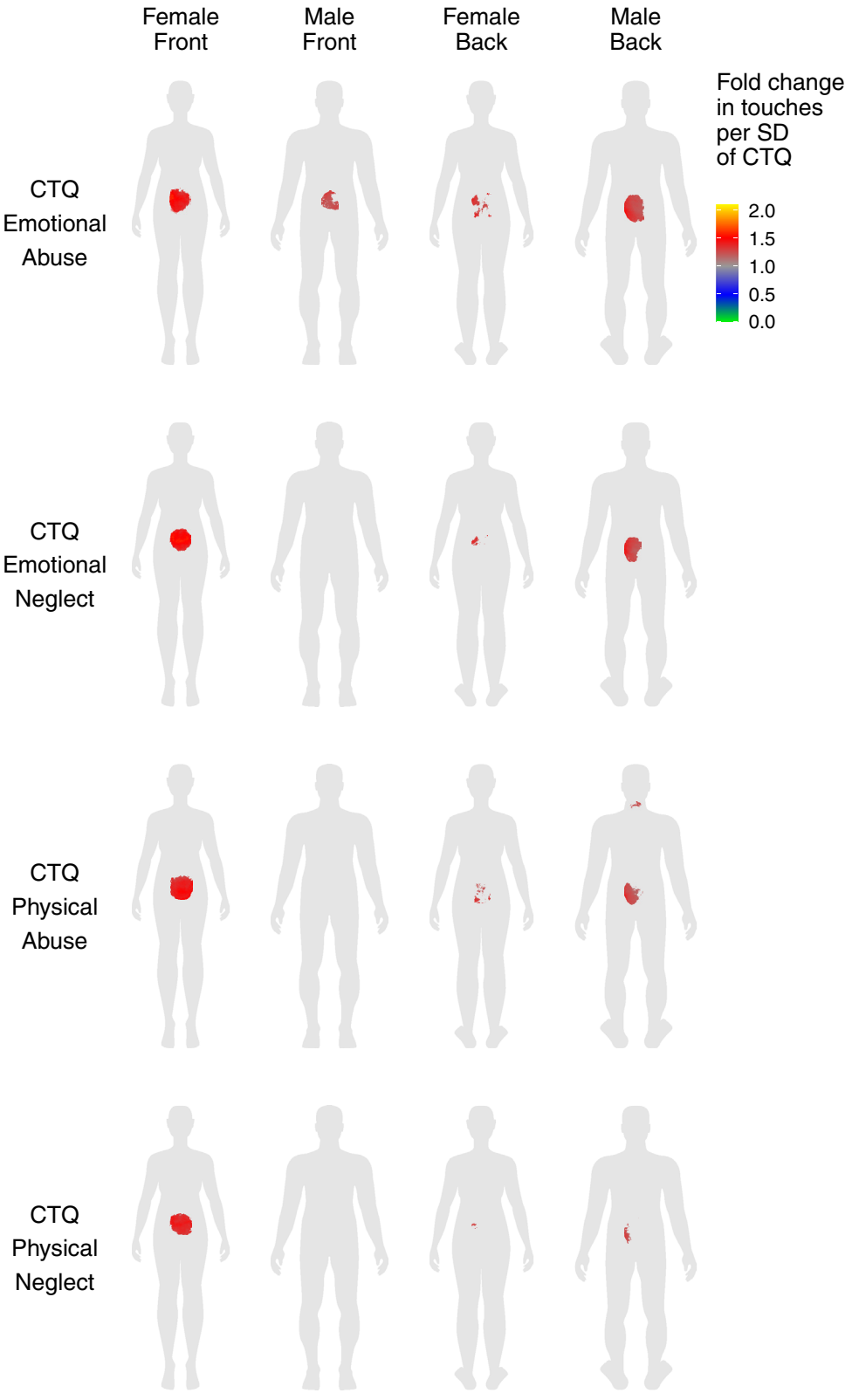

Fig. 3. Locations of negative activation associated with specific types of childhood maltreatment. The four measured subscales of the CTQ were examined individually as predictors of negative activation in the body. Regions identified as associated with each CTQ subscale were largely the same as those identified as associated with the CTQ total score. Abuse appeared to have stronger associations than neglect, for both the emotional and physical domains. Emotional abuse appeared to have the strongest association with negative activation, including to the extent that it predicted negative activation in the abdomen for male participants, which was not observed for CTQ total score.

areas as for the CTQ total score, i.e., the lower abdomen in females and the lower back in males and females.

Discussion

We conducted a large-scale experience sampling study in a general population to examine and localize the associations between childhood maltreatment and later-life negative somatic sensations. As hypothesized, we showed that childhood maltreatment is positively associated with negative activation in the body as measured by body maps. In exploratory analyses, we also found positive associations between each of the four studied subtypes of childhood maltreatment (emotional abuse, emotional neglect, physical abuse, and physical neglect) and negative activation in the body. We found that these associations were localized in females to the abdomen and lower back, and in males to the lower back, except

for emotional abuse, which was also associated with negative activation in the abdomen in males.

There are several possible interpretations for the observed associations between childhood maltreatment and negative activation measured via body maps. First, given that individuals were prompted to report "negative activation," it is possible that some of what the body map touch counts were measuring was negative affect rather than exclusively unpleasant somatic sensation. However, the task instructions repeatedly anchored participants to focus on bodily sensations. Specifically, the word "body" appeared three times in the initial prompt, and participants were presented with a map of the body and instructed to select one or more physical locations. They were also provided with a somatosensory example of a localized negative activation ("a pounding in the back of your head"). Furthermore, we conducted sensitivity analyses that adjusted for average affect over the study period. The effect size and significance of the association between body map touch count and CTQ total score was essentially unchanged, suggesting that negative affect was not responsible for the association between childhood maltreatment and negative activation in the body.

A second possible interpretation for the observed associations is that heightened negative somatic sensations in individuals with a history of childhood maltreatment may indicate organic pathology in the affected areas. However, peripheral causes of pain or discomfort such as cancer, inflammatory bowel disease, and osteoarthritis increase in prevalence with increasing age (30). If the body map task was mainly detecting somatic symptoms resulting from medical illness, we would expect to see a positive association between age and the number of body map touches. Rather, a significant negative, linear association was observed.

Instead, the associations between childhood maltreatment and increased body map touch counts may be best interpreted as reflecting increased somatization, i.e., the experiencing of somatic sensations that do not have pathology in the affected regions of the body as their root cause (6). There are two main mechanisms that might mediate this increased somatization. First, there is some evidence that individuals with experiences of childhood maltreatment have sensitized autonomic nervous responses to stressors in later life, and they may therefore have more pronounced or frequent changes in physiological parameters such as heart rate or contractility, breathing rate, or gut motility (31–34). These changes might then generate interoceptive sensory signals that, over time, come to be perceived as unpleasant by virtue of their association with stressors and negative emotional states. However, our localization results do not concord well with this hypothesized mechanism. In the chest, where key autonomic nervous target organs (the heart and lungs) are located, mean levels of negative activation were very low, and we observed an association in both genders between childhood maltreatment and negative activation in the lower back, where no autonomic nervous target organs are located.

A final potential mechanism, also involving the central nervous system, might best explain the increased somatization we observed in individuals with childhood maltreatment. Particularly over the last two decades, it has become increasingly clear that sensory experiences result from reconciling top–down predictions (i.e., expectations or priors) about bottom–up incoming sensory signals with the incoming sensory signals themselves (35–38). Especially when incoming signals are inconsistent or ambiguous, expectation can dominate conscious experience. Indeed, the hypothesis that somatization involves strong (i.e., precise) top–down predictions regarding regions of the body that supply relatively ambiguous (i.e., imprecise) incoming sensory information now has significant evidentiary support (39–45). How individuals come to develop these overly strong predictions is still unclear, but the process is known to be shaped by negative affect, negative nonsensory expectations, and the perception of threat (40, 42, 43). The depression and anxiety (46–48), and psychological stress sensitivity (49–51), that can follow childhood maltreatment might therefore contribute to the development of inaccurate sensory predictions and thus perceptions in such individuals. This hypothesis also offers an elegant explanation for the observed localization to the abdomen and lower back of the association between childhood maltreatment and somatization. Specifically, incoming sensory information in these areas may be more ambiguous and less precise, or more variable and less predictable, than in other areas, and therefore perception may be more easily dominated there by expectation (42, 45).

This framework also offers a possible explanation for the sex difference observed in the localization results. In females, childhood maltreatment generally and each examined subtype showed localized associations in the lower back and abdomen, whereas in males, these measures only showed localized associations in the lower back, except for emotional abuse, which also localized to the abdomen. If the explanation for localization to certain regions in general is that those regions have uniquely high incoming sensory ambiguity, providing fertile ground for childhood maltreatment to scale up top–down expectations that then dominate experience, perhaps that is also the reason for this sex difference in localization. Birth-assigned females typically have lower abdominal or pelvic reproductive organs and attendant sensorineural innervation that birth-assigned males do not have (52). The fact that abdominal or pelvic somatosensory information comes not just from organs such as the small and large intestine but also additional structures such as the uterus could potentially result in greater ambiguity in bottom–up sensory information regarding the state of the abdomen and pelvis. The brain's somatosensory model of the abdomen may then be more vulnerable to sensory expectation, which is influenced by cognitive and affective processes (40, 42, 43). As to why there is no sex difference for emotional abuse, it may be that emotional abuse has a sufficiently potent impact on expectation that comparatively subtle sex differences in afferent signaling do not significantly affect perception. This hypothesis is supported by our finding that emotional abuse had the largest effect size relationship with body map touch count of all studied maltreatment subtypes. Ultimately, however, gender-specific patterns in the localization of somatic symptoms related to childhood maltreatment underscore the need for further research into the underlying neurobiological and psychological mechanisms.

Our results replicate prior evidence that links childhood maltreatment to increased somatic symptoms in adulthood (6, 7, 9–18). While these symptoms may not necessarily map onto medical diagnoses or organic diseases, they often cause significant distress (7). Moreover, negative interoceptive sensations, like stomach tension or an elevated heart rate, can influence decision-making, cognition, and emotion (53, 54). These sensations might also trigger trauma-related memories and defensive reactions, creating a positive feedback loop that can contribute to retraumatization (55).

Contrary to some research that identified links between only specific maltreatment types and adult somatic symptoms (7, 12), in our large sample, we found that all four maltreatment subtypes studied were significantly related to increased somatic symptoms. This discrepancy may relate to a key difference in the modeling approach. In these earlier studies, analyses simultaneously included all CTQ subscales as predictors. In such models, even where multicollinearity is demonstrated to be low, the interpretation of the

coefficients and associated test statistics is fundamentally different compared to when separate models are fit for each CTQ subscale. For example, in a model with multiple CTQ subscales, the *P*-value for physical abuse tests whether, if an individual's history of emotional abuse, emotional neglect, and physical neglect are all known, physical abuse still has predictive value with respect to somatic symptoms. While such tests may be able to shed some light on causal relationships between different forms of childhood maltreatment and somatic symptoms, the questions they ask are different to the descriptive, practical questions that we ask here. We focus on whether individuals with higher levels of each type of childhood maltreatment have higher levels of somatic symptoms. To ask these questions, it is important that subscales be entered into separate models. However, for total touch count on the front and back body maps, we also conducted lasso regression analyses that included multiple predictors simultaneously. In these models, the only CTQ subscale retained as a predictor of body map touches was emotional abuse, suggesting that if one's level of emotional abuse is known, the other subscales may offer little additional predictive value with respect to somatic symptoms. Nevertheless, it must be emphasized that, descriptively, individuals with higher levels of emotional neglect, physical abuse, and physical neglect did exhibit higher somatic symptoms. Relatedly, the abuse subscales consistently had larger effect sizes than the neglect subscales, perhaps suggesting that certain dimensions of childhood adversity (56), such as experiences characterized by threat (abuse) vs. deprivation (neglect), may be more strongly linked to adult somatization.

Our findings have several practical implications. First, they help to define and increase awareness of the psychosomatic consequences of childhood maltreatment, potentially helping to normalize them from the perspective of both affected individuals and their medical providers. Second, they suggest that clinicians should consider enquiring about maltreatment histories in patients with medically unexplained symptoms, especially pain in the abdomen or lower back. Third, our findings hint at possible approaches to reducing unpleasant somatic sensation in individuals with a history of childhood maltreatment. They suggest that psychological treatments may be particularly beneficial for affected individuals. For example, psychotherapeutic approaches such as pain reprocessing therapy, which emphasizes reappraisal of primary chronic back pain as due to benign central nervous processes, may be useful (57). It may also be prudent to leverage placebo responses, possibly even open-label placebo responses, which has been shown to be effective in irritable bowel syndrome (58). Finally, some somatic-based psychotherapies, such as somatic experiencing, use somatic sensations as core elements of trauma therapy to directly address the physical manifestation of trauma (55).

Our study is not without limitations, one of which is the inability to know with certainty what exactly participants were reporting via the body maps that was responsible for the associations with childhood maltreatment. While constructs like negative affect and physical illness are less likely to be contributing to the association between childhood maltreatment and increased reported negative activation in the body, these explanations cannot be definitively ruled out. Relatedly, although the increased negative activation appears to largely reflect unpleasant somatic sensation, it is unknown what the quality of that somatic sensation was, including whether it was painful or nonpainful, such as a tension, tightness, or constriction. The time course of the somatic sensations is also unknown, including whether or not they are stable across shorter periods such as the day of measurement and longer periods like recent weeks. We also have limited ability to shed light on the likely neuropsychiatric mechanisms of the observed associations. A major limitation of our study is that we did not measure sexual abuse and so were unable to examine its association with somatic sensation. In the future, research using the CTQ should administer the sexual abuse items, because more research on the long-term consequences of sexual abuse is needed, and because there is substantial evidence that inquiring about sexual abuse in research settings does not retraumatize individuals (59). Further, many subjects who provided body map data did not provide CTQ data, which was a function of the opt-in nature of the latter measure. Whether the observed relationships would have differed in subjects who did not opt in is unclear. Finally, it was only possible to measure childhood maltreatment via retrospective self-report, which can be influenced by recall and reporting biases (60).

Altogether, we show here that childhood maltreatment has localized associations with unpleasant somatic sensations in the abdomen in females and the lower back in both females and males. We show that four domains of childhood maltreatment, specifically emotional abuse, emotional neglect, physical abuse, and physical neglect, all demonstrate these associations and that in males, emotional abuse was additionally associated with negative somatic sensation in the abdomen. We present arguments that these somatic perceptions may be largely psychosomatic in nature and specifically that they may be driven by alterations to brain circuits and networks that underpin predictive processing in somatosensory perception. We hope that increased awareness of the somatosensory consequences of childhood maltreatment can help to normalize them and encourage psychotherapeutic approaches to reducing symptoms and associated distress.

Materials and Methods

Participants and Procedures. Data were collected as part of the MyBPLab study (29), a large study conducted via a mobile phone app that could be downloaded from the Google Play Store. We used data from the second wave of the study (MyBPLab 2.0), which was conducted from March 2019 to December 2021. Individuals downloaded the app on a compatible phone, affirmed that they were 18 y or older, passed an English fluency quiz (the app was only available in English), and then were presented with a consent form to participate in a 21 d study. Following consent, participants provided demographic information including age, gender identity, race, ethnicity, education, household income, country location, and zip code/country code. The study was approved by the International Review Board at the University of California, San Francisco (Application #19-27169). Sample characteristics are presented in Table 3, and attrition information is available in *SI Appendix, Supplementary Methods*.

Childhood Maltreatment Measurement. At any point during the study, participants could select an option to "enhance their profile." When selected, participants could view a variety of topics that were presented as surveys that helped researchers obtain additional information about the participants. The topics were presented in lay language such as "your social life" or "connection with others." A total of 23 items from the CTQ Short Form (61) appeared under the topic "your early life," including five items for each of four subtypes of childhood maltreatment (emotional abuse, emotional neglect, physical abuse, and physical neglect), and three items measuring minimization/denial. The five items measuring sexual abuse were not administered. Participants were presented with the prompt, "Think back on your childhood. Please indicate how true each statement is for you", and an explanation of the response scale ranging from "1 = never true" to "5 = very often true". The stem "When you were growing up…" was then presented above the set of statements for participants to rate their agreement with.

Body Map Task. On the morning of day 1 between 7 and 10 am and repeated every third morning, participants were prompted to complete the body map task. Participants were presented with a silhouette of a body that matched their gender identity. The back of the body was presented first with the title "Body Map–Back" and the following prompt: "Using this body map, tap on the body to select where

Table 3. Sample characteristics

Characteristic	Overall (N = 2,234)	Female (N = 727)	Male (N = 1,507)
Age	44.6 (12.6)	43.9 (11.8)	44.9 (12.9)
Education			
2 y college degree	280 (13%)	109 (15%)	171 (11%)
4 y college degree	584 (26%)	174 (24%)	410 (28%)
Graduate school degree	500 (23%)	139 (19%)	361 (24%)
High school/GED	272 (12%)	84 (12%)	188 (13%)
No high school diploma	45 (2.0%)	11 (1.5%)	34 (2.3%)
Some college	529 (24%)	205 (28%)	324 (22%)
Race			
Latinx White or European	113 (5.1%)	31 (4.3%)	82 (5.4%)
Non-Latinx Asian	135 (6.0%)	23 (3.2%)	112 (7.4%)
Non-Latinx Black or African American	89 (4.0%)	43 (5.9%)	46 (3.1%)
Non-Latinx Multiracial	81 (3.6%)	33 (4.5%)	48 (3.2%)
Non-Latinx White or European	1,546 (69%)	531 (73%)	1,015 (67%)
Other/unknown	270 (12%)	66 (9.1%)	204 (14%)
CTQ total score	37.0 (14.7)	40.5 (16.6)	35.3 (13.3)
CTQ emotional abuse	10.1 (5.1)	11.8 (5.7)	9.2 (4.6)
CTQ physical abuse	8.0 (3.9)	8.6 (4.5)	7.7 (3.4)
CTQ emotional neglect	11.2 (5.0)	11.9 (5.3)	10.9 (4.9)
CTQ physical neglect	7.7 (3.3)	8.2 (3.6)	7.5 (3.2)
CTQ minimization/denial	0.4 (0.8)	0.4 (0.8)	0.5 (0.9)
Emotional abuse (at least moderate)	609 (27%)	298 (41%)	311 (21%)
Emotional neglect (at least moderate)	591 (26%)	241 (33%)	350 (23%)
Physical abuse (at least moderate)	498 (22%)	202 (28%)	296 (20%)
Physical neglect (at least moderate)	508 (23%)	209 (29%)	299 (20%)
At least moderate CM on any subscale	990 (44%)	389 (54%)	601 (40%)
Affective valence	0.7 (0.4)	0.7 (0.4)	0.8 (0.3)
Affective arousal	0.3 (0.3)	0.3 (0.3)	0.3 (0.3)

Summary statistics are presented for the sample contributing to the analyses of the association between the CTQ total score and per-pixel touch count. Values are given as mean (SD) or n (percentage). CTQ: Childhood Trauma Questionnaire; CM: childhood maltreatment; GED: General Educational Development.

you are currently feeling the most negative 'activation,' such as a pounding in the back of your head." Participants could either tap "Next" to start the task or "Skip" to skip it. After selecting "Next," the prompt changed to "Tap to add intensity." No other text or instructions were provided. The term "negative activation" was chosen to allow participants to potentially report a wide range of unpleasant, undesirable, or concerning sensations, such as pain, fatigue, tingling, tightness, constriction, or tension. We avoided the word "arousal" which can be misinterpreted to mean sexual arousal. Participants could tap up to 20 times on the body map, with the total number of taps being referred to as the total touch count, serving as a measure of intensity. With each tap, a red circle appeared on the body map to indicate the selected area. Red selection circles were semitransparent such that where selection circles overlapped, a darker red was presented to provide a visual sense of intensity. Once participants finished tapping on the back of the body map, they clicked "Next" to progress to the next screen, at which point the task commenced again with the title "Body Map–Front" and a corresponding silhouette of the front of the body, and the same instructions to tap on the body to indicate felt "negative activation."

Affect Grid Task. For use in sensitivity analyses, measures of affective valence (positive vs. negative) and affective arousal (high vs. low) were obtained using an affect grid (62, 63). These constructs were measured every third study day between 10 am and 4 pm, beginning on day 2. Participants were presented with a screen containing the prompt, "How are you feeling now? Select all that apply," above a grid of four squares. The top two squares were labeled, "Positive & low activated, such as calm, relaxed, content, happy, sleepy, loved," and "Positive & high activated, such as energized, alert, inspired, happy, proud, excited." The bottom two squares were labeled, "Negative & low activated, such as bored, tired, sad, depressed, disengaged, checked-out," and "Negative & high activated, such as nervous, afraid, angry, upset, hostile, disgusted." Check-ins were classified as reporting positive affect (coded as 1) if either "positive" square was selected and neither "negative" square was selected, and negative affect (coded as 0) if either "negative" square was selected and neither "positive" square was selected. Check-ins were classified as reflecting high arousal (coded as 1) if either "high activated" square was selected and neither "low activated" square was selected, and low arousal (coded as 0) if either "low activated" square was selected and neither "high activated" square was selected. Average affective valence and arousal (range 0 to 1 for both) over the study period were then calculated for each participant, with higher values reflecting more positive affect or higher arousal respectively.

Data Analysis. Participants were included in each analysis if they provided data for all predictors in the relevant statistical model, including data sufficient for calculation of the relevant CTQ total score or subscale scores. Participants who touched on only the front or back body map were excluded from the main analyses so that results from front and back body maps referred to the same set of individuals and could be directly compared. However, sensitivity analyses were performed that did not use this exclusion criterion. While participants were able to complete multiple body map check-ins over the course of the study, nearly half (46%) completed the task only once, so only the first check-in was used in analyses.

The CTQ total score was calculated by summing the values for the 20 administered items measuring abuse and neglect, for a theoretical maximum score of 100. Scores were also calculated for each CTQ subscale (emotional abuse, physical

abuse, physical neglect, and emotional neglect) by summing the values for the five items corresponding to each subscale (see *SI Appendix*, Table S5 for item numbers). For use in sensitivity analyses, a minimization/denial score (range 0 to 3) was calculated based on CTQ items 10, 16, and 22, as described previously (64). Reverse coding was resolved before score calculation. Prorated scores were calculated if a participant provided values for two-thirds of the required items; otherwise, the score was considered missing. For the purpose of describing sample characteristics, and for calculating the number of different maltreatment types each participant experienced, participants were categorized as having less than moderate vs. at least moderate childhood maltreatment on each CTQ subscale using standard cutoffs, provided in *SI Appendix*, Table S5 (61).

To examine localized associations between a given predictor variable and touches on each body map, a separate regression model was fit for each pixel of the body map. To minimize spurious statistically significant associations, hypothesis testing was not performed in areas exhibiting a low average touch count. These areas were defined based on an arbitrary threshold of less than 0.2 touches per pixel, which was selected based on visual inspection of the average touch count maps. *P*-values for per-pixel touch counts were adjusted for multiple comparisons using Bonferroni correction. Pixels with statistically significant associations after multiple comparisons correction are shown on body map visualizations, with the color of each pixel representing the effect size of the association.

Front and back body maps were always analyzed separately. In analyses of total touch count, males and females were included in the same model, whereas per-pixel analyses could only be performed for each gender separately. Analyses of the association between total touch count and CTQ total score included the covariates age, gender, race, and education. Covariates that were not statistically significant (i.e., race and education) in these models were not included in any further models. Thus, all other analyses of total touch count covaried for age and gender, while analyses of per-pixel touch count covaried for age. Correlation coefficients between all continuous predictor variables are provided in *SI Appendix*, Fig. S1.

All analyses were performed in R v4.3.3 and all visualizations were produced using *ggplot2* and *patchwork*. In analyses of both total touch count and per-pixel touch count, Poisson regression was used. For models of total touch count, the model assumption of linearity in the log scale was met for all CTQ scores, as confirmed using residual plots. Therefore, to increase statistical power, for most analyses, these scores were kept continuous rather than binarized or made categorical. Where multicollinearity was anticipated (i.e., in the models that simultaneously included multiple CTQ subscale scores as predictors), lasso Poisson regression was performed using *glmnet*. Otherwise, no multicollinearity was observed in any model of total touch count, given that all variance inflation factor (VIF) or generalized VIF values were less than two. For testing predictor significance, the car package was used to perform F tests in analyses of total touch count and likelihood ratio tests in analyses of per-pixel touch count. Continuous predictors were z-scored prior to model fitting, and resulting model coefficients were exponentiated to give effect sizes in the form of fold change in the outcome per one SD of the predictor. Partial correlations were calculated by taking the square root of the partial eta squared, calculated using the effectsize package together with F tables. Tukey adjustment was used for post hoc testing.

Data, Materials, and Software Availability. Data and analysis code will be made available at https://osf.io/2h4vy/ (65).

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