The somatosensory system in anorexia nervosa: A scoping review

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Abstract
Anorexia nervosa (AN) is a severe psychiatric disorder characterized by a number of symptoms including food restriction and body perception distortions. In the present scoping review, we outline the current literature on sensory submodalities related to the somatosensory system in AN including affective touch, haptic perception, interoception, nociception, proprioception, and tactile perception as well as multisensory integration. The evidence suggests that individuals with AN exhibit abnormalities in multisensory integration, discrimination (but not detection) of complex haptic and tactile stimuli, and reduced sensitivity to nociceptive stimuli. This review provides an outline of the current literature, identifies gaps within the literature, and suggests novel directions for future research.

Keywords
Affective touch, anorexia nervosa, eating disorder, experimental psychopathology, haptic, interoception, multisensory, nociception, proprioception, tactile

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Introduction
Anorexia nervosa (AN) is a complex and serious psychiatric disorder characterized by food restriction, extreme fear of weight gain, persistent behavior that impedes weight gain, and a disturbance in body perception (American Psychiatric Association, 2013). AN has a high mortality rate (approximately 5% per
decade of illness) and is generally resistant to treatment (American Psychiatric Association, 2013; Peterson et al., 2016; Ward et al., 2015). Interestingly, it has been found that individuals with AN exhibit abnormalities in the somatosensory system and multisensory integration of stimuli involving somatosensory information (Gaudio et al., 2014; Keizer et al., 2011, 2012).

We conducted this review of research that examined the performance of individuals with AN on somatosensory-related unimodal and multisensory tasks (with a behavioral component) because recent evidence suggests that individuals with AN exhibit alterations to the somatosensory system (Keizer et al., 2012; Spitoni et al., 2015). Our discussion of the literature is separated by the specific somatosensory submodalities involved in the task. This organization is consistent with the Research Domain Criteria put forth by the National Institute of Mental Health as well as previous reviews on this topic (Gaudio et al., 2014). The somatosensory submodalities covered in the present scoping review will include affective touch, haptic perception, tactile perception, nociception, proprioception, and interoception. We also discuss multisensory tasks that involve the aforementioned sensory submodalities. A theme central to our discussion of the submodalities reviewed is whether the available evidence suggests that the observed differences are state-dependent or emerge from a preexisting trait. Such a distinction is important because it will help us determine what aspects are likely to be amenable to treatment and could potentially give us an additional way to identify individuals at risk of developing AN (particularly differences that seem to be preexisting traits). To address this theme, we (1) summarize what is known based upon the available data, (2) identify gaps within this literature, and (3) suggest future avenues of research. A better understanding of this topic will aid in the development and refinement of treatments aimed at reducing body perception distortions in individuals with AN.

**Method**

To be included in this scoping review, an article must have met the following criteria. (1) The article must examine at least one somatosensory submodality and have a behavioral component. (2) The article must include statistical analyses that put individuals with AN in a separate group (i.e., their data are not lumped together with other eating disorders) and included a control group of healthy participants (HCs). Studies with samples of individuals who no longer met the body mass index (BMI) requirements for AN (eating disorder not otherwise specified—anorexia nervosa [EDNOS-AN]), but still had symptoms of the disorder, were included as well. (3) The article had to be published in English prior to January 1, 2020 (or accepted for publication prior to this date). All articles were found using the following databases: PsychInfo and Web of Science (All Databases). The search terms used and the number of articles they yielded can be found in Table 1. All the resulting articles were evaluated to see if they met the criteria for this review by the first author (M.T.). The articles that met the aforementioned criteria were then separated by sensory submodality and clustered by research group, to allow the reader to get a better sense of whether independent groups were producing similar findings (see Supplemental Material). Research group was determined by common authorship (at least one author) across papers.

**Results**

A total of 57 articles were found to meet the inclusion criteria for this review (see Table 2 for a breakdown of how many articles met the criteria for inclusion in the present article). A detailed description of each study included in the present review, also broken down by submodality, can be found in the Supplement.

**Nociception**

Nociception refers to the detection of a noxious stimuli via nociceptors, which is usually experienced as painful (Dubin & Patapoutian, 2010). Nociception is one of the most widely studied sensory modalities in AN. Table S1 lists studies included in this portion of the review and Table S2 divides those studies by research group. Two types of nociceptive stimuli have been utilized in this literature: thermal and mechanical.

Of the studies that utilized thermal stimuli, 61.54% (from four independent research groups) provided evidence suggesting that people with AN exhibit an elevated nociceptive threshold (i.e., need a stronger stimulus to induce the perception of pain; Bär et al., 2006, 2013, 2015; de Zwaan et al., 1996; Lautenbacher et al., 1991; Papezová et al., 2005; Yamamotová et al., 2012, 2017). The elevated thermal pain threshold exhibited by individuals with AN suggests
changes in the processing of thermal nociceptive stimuli.

Interestingly, several studies that found a difference between individuals with AN and HCs also found a significant negative correlation between the skin temperature of individuals with AN and thermal pain thresholds (assessed using thermodes; Lautenbacher et al., 1990, 1991; Papezová et al., 2005). In other words, they found that lower skin temperatures were associated with higher thermal pain thresholds. It was also found that there was a negative correlation between dehydroepiandrosterone (DHEA) levels and thermal pain thresholds in individuals with AN (Yamamotová et al., 2012). Furthermore, there was a negative association between dehydroepiandrosterone sulfate (DHEAS) and thermal pain thresholds when the AN and HC groups were combined. These findings suggest that the elevated thermal pain threshold exhibited by individuals with AN may be the result of cardiovascular and endocrine alterations resulting from malnutrition.

Of the studies that did not find an elevated thermal pain threshold, two had samples composed of individuals who recovered from AN, who exhibited lower thermal pain thresholds (Krieg et al., 1993), and who reported more pain intensity than HCs (although in one case, the thermal pain threshold was not determined; Strigo et al., 2013). In the case of Krieg et al. (1993), it was also found that recovered individuals with a good outcome (i.e., achieved a BMI over 20) had higher skin temperatures. Two studies found that individuals with AN exhibited elevated thermal pain thresholds, but the difference did not reach the level of statistical significance (Lautenbacher et al., 1990; Table 2.

Table 1. Search terms used to obtain the articles in the present scoping review.

| Initial search term   | Additional search terms used | Number of search results produced by PsychInfo | Number of search results produced by Web of Science |
|-----------------------|-----------------------------|-----------------------------------------------|-------------------------------------------------|
| Anorexia              | Affective touch             | 3                                             | 15                                              |
|                       | Haptic                      | 10                                            | 34                                              |
|                       | Haptic perception           | 12                                            | 31                                              |
|                       | Interoception               | 26                                            | 97                                              |
|                       | Multisensory                | 12                                            | 38                                              |
|                       | Nociception                 | 2                                             | 216                                             |
|                       | Pain                        | 416                                           | 8,275                                           |
|                       | Proptioception               | 8                                             | 20                                              |
|                       | Tactile                     | 24                                            | 68                                              |
|                       | Tactile perception           | 8                                             | 44                                              |

Anorexia nervosa

| Affective touch         | 3                                             | 15
| Haptic                 | 10                                            | 33
| Haptic perception      | 12                                            | 30
| Interoception           | 25                                            | 90
| Multisensory           | 11                                            | 38
| Nociception             | 1                                             | 153                                             |
| Pain                   | 204                                           | 1,910                                          |
| Proptioception          | 8                                             | 16                                              |
| Tactile                | 22                                            | 56                                              |
| Tactile perception     | 8                                             | 42                                              |

Note. The initial search term refers to the first word/phrase used as a search query. The additional search term was the word/phrase used in conjunction with the initial search term.

Table 2. The number of articles that met inclusion criteria separated by sensory modality.

| Modality                  | Number of articles included |
|---------------------------|-----------------------------|
| Affective touch           | 3                           |
| Haptic perception         | 6                           |
| Interoception             | 12                          |
| Multisensory integration  | 14                          |
| Nociception               | 14                          |
| Proprioception            | 2                           |
| Tactile perception        | 6                           |

Note. The number of articles that met inclusion criteria.
The remaining study used a cold thermal stimulus (i.e., the cold pressor task) rather than heat (Goldzak-Kunik et al., 2012). There are several limitations of this research that should be noted, including the fact that only one study has used cold thermal stimuli and all of the studies administered nociceptive stimuli to the limbs not the trunk. Overall, it appears that these changes are state-dependent rather than a trait and thus amenable to intervention.

Unlike thermal pain, there is currently no evidence that suggests individuals with AN exhibit elevated mechanical pain thresholds (see Table S2), although evidence on this is limited. Both of the studies that utilized mechanical pain stimuli found no difference between individuals with AN and HCs (De Zwaan et al., 1996; Raymond et al., 1999). However, in the case of de Zwaan et al. (1996), individuals with AN were found to have elevated thermal pain thresholds despite a lack of difference in mechanical pain threshold.

The data reviewed above suggest that individuals with AN exhibit higher thermal pain thresholds on their extremities than HCs, prior to weight restoration. After recovery, thermal pain thresholds are comparable to HCs (Krieg et al., 1993) or may even be lower than HCs (Strigo et al., 2013). Based on the apparent restoration of normal thermal pain thresholds after recovery from AN, it is likely that differences in thermal pain sensitivity are state-dependent, perhaps as a result of malnutrition. The exact mechanisms underlying this difference remains elusive; however, the research implies that alterations to peripheral blood flow and hormone levels may be involved. DHEA/DHEAS is known to be related to thermal pain thresholds (i.e., higher levels are associated with lower thresholds; Yamamotová et al., 2012) and reduced blood flow is known to be associated with reduced sensitivity to thermal stimuli (Guergova & Dufour, 2011).

**Affective touch**

Affective touch is a term that refers to touch that alters affect, in a positive or negative manner depending upon the context (Marshall et al., 2019; McGlone et al., 2014). Affective touch is commonly experienced during social interactions and is known to play a role in affiliative behavior (e.g., gentle stroking, grooming, etc.) as well as the formation of relationships with others (Morrison et al., 2010). Affective touch is believed to be detected by C Tactile (CT) and A-Beta nerve fibers, each of which forms distinct ascending pathways that terminate in the posterior insula (Crucianelli et al., 2016; Russo et al., 2020).

To date, there have only been three studies (conducted by three independent groups) that examined affective touch in AN, all of which examined positive affective touch using gentle stroking of the skin at slow speeds (1–10 cm/s; see Table S3; Crucianelli et al., 2016; Davidovic et al., 2018). Of the three studies, two included individuals currently diagnosed with AN, and they found that they experienced positive affective touch as less pleasant than HCs, when stroking at CT-optimal velocity was applied to the forearm (Crucianelli et al., 2016; Davidovic et al., 2018). Furthermore, this experience did not change as a result of social stimuli (i.e., faces with accepting, rejecting, or neutral expressions), as it normally does in HCs, suggesting this is the result of bottom-up changes (Crucianelli et al., 2016). However, after weight restoration, this difference (i.e., reduced pleasantness ratings) does not seem to persist (Bischoff-Grethe et al., 2018). Furthermore, individuals who recovered from AN experienced CT optimal stroking of their hand as more intense than HCs (Bischoff-Grethe et al., 2018).

The available data reveal that individuals with AN likely experience positive affective touch as less pleasant than HCs until after weight restoration, at which point their perception of it is comparable to HCs (or more intense). This change in perceptual experience suggests that this difference is state-dependent, that is, resulting from malnutrition rather than a preexisting trait.

**Tactile perception**

Tactile perception refers to obtaining sensory information about stimuli through passive contact with the skin (i.e., it does not involve active manipulation; Dahiya & Valle, 2013). Tactile perception has only been the subject of six studies (four of which were conducted by the same research group; see Tables S4 and S5) making it a less studied submodality (Epstein et al., 2001; Keizer et al., 2011, 2012, 2019; Mergen et al., 2018; Spitonì et al., 2015). Discussion of the tasks used in each study will be separated by whether they required tactile detection or tactile discrimination.

Tactile detection is a term that refers to the ability to detect a tactile stimulus (Møller, 2014). One
measure utilized in multiple studies (Keizer et al., 2012; Spitoni et al., 2015) was the Von Frey Test (a measure of sensitivity to tactile pressure). It was found that individuals with AN did not differ from HCs when their arm, sternum, or thigh was stimulated (Keizer et al., 2012; Spitoni et al., 2015). However, conflicting results were obtained when the abdomen was stimulated, namely one study found no difference (Spitoni et al., 2015), whereas the other found individuals with AN had a lower pressure detection threshold on the right side of their abdomen (Keizer et al., 2012). The two remaining studies that used measures of tactile detection found that individuals with AN did not differ from HCs when identifying the location of a tactile stimulus on their back or abdomen (Mergen et al., 2018) or on one of their fingers (regardless of whether or not their eyes were open; Epstein et al., 2001). However, individuals with AN performed significantly worse than HCs when they had to identify two fingers that were stimulated simultaneously while their eyes were shut prior to treatment only (Epstein et al., 2001). Overall, 75% of the studies that utilized measures of tactile detection suggest a lack of difference between individuals with AN/EDNOS-AN and HCs. In other words, individuals with AN do not show a consistent impairment in their ability to detect the presence of tactile stimuli and in some cases may be more sensitive to tactile stimuli than HCs (e.g., Keizer et al., 2012).

The remaining tasks used to study tactile perception in individuals with AN were measures of tactile discrimination. Tactile discrimination refers to the ability to differentiate between sources of tactile information (Møller, 2014). Four of the studies used tasks that entailed judging the distance between two tactile stimuli (i.e., the tactile estimation task and the distance task; Keizer et al., 2011, 2012, 2019; Spitoni et al., 2015). All four of these studies found that individuals with AN tended to overestimate the distance between tactile stimuli when they were administered to the abdomen, forearm/underarm, sternum, and thigh (Keizer et al., 2011, 2012, 2019; Spitoni et al., 2015). Furthermore, the work of Spitoni et al. (2015) suggests that this difference is more pronounced when stimulation is administered on the horizontal axis, suggesting that individuals with AN experience their body as wider. This difference seems to persist after treatment, unless hoop training is used (see Keizer et al., 2019, for more information). Furthermore, individuals with AN have been found to exhibit differences on a measure called the two point test (which entails making determinations of whether or not they are receiving tactile stimulation from one or two points while varying the distance between the two points; Keizer et al., 2012; Spitoni et al., 2015). Namely, there had to be a larger distance between the two points on the abdomen, arm, and thigh for the individuals with AN to be able to feel the difference (Keizer et al., 2012; Spitoni et al., 2015). While individuals with AN have been found to exhibit difficulties discriminating the distance between tactile stimuli, they do not appear to have difficulty discriminating which of two stimuli had a longer duration (Spitoni et al., 2015).

Taken as a whole, the existing research on tactile perception in AN suggests that individuals with AN have poorer tactile discrimination than HCs (namely when it involves spatial discrimination) but do not differ with regard to tactile detection. This impairment in tactile discrimination appears to be specific to the extremities (i.e., arms and thighs) as well as the more lateral portions of the trunk (i.e., the abdomen; Keizer et al., 2011, 2012, 2019; Spitoni et al., 2015). This impairment seems to persist after treatment (with the exception of hoop training; Keizer et al., 2019), suggesting the possibility that this may be a trait rather than a malnutrition-induced state. However, this interpretation is complicated by the fact that 50% of the studies (Keizer et al., 2011, 2012) reported individuals with AN and individuals with AN who no longer met the BMI/amenorrhea criteria for it (EDNOS-AN) in aggregate. Individuals’ performance on the tasks described in the manuscripts was reported to be comparable.

Unfortunately, there has not been any research examining the association between the pathophysiological changes associated with AN and tactile discrimination. A couple of studies have found evidence of reduced nerve conduction velocity (McLoughlin et al., 1998; Melchiorri & Rainoldi, 2008) and selective atrophy of type II nerve fibers (i.e., Aβ fibers) in the vastus lateralis (i.e., a muscle in the thigh) of individuals with AN (McLoughlin et al., 1998). As mentioned above, individuals with AN have been found to exhibit poor tactile discrimination in this region, suggesting that this may be an underlying mechanism (Spitoni et al., 2015). Impaired performance on tactile discrimination tasks (such as the two-point test) has been suggested to be indicative of reduced nerve innervation density supporting this possibility (Shooter, 2005). This possibility will be elaborated on below.
Haptic perception

Haptic perception refers to obtaining sensory information through the active manipulation of an object (Gibson, 1966; Tresilian, 2012). Haptic perception in AN has been the subject of six studies (four of which were conducted by the same group; please see Table S6 for a detailed description of the studies included). Of these studies, 83.33% (and all, but one, were conducted by the same research group; see Table S7) suggest that individuals with AN exhibit a deficit in haptic perception. A total of three tasks were used to examine haptic perception in AN: the sunken relief task, the right parallel task, and a shape size evaluation task (both manual and oral variants).

The sunken relief task is a haptic task in which an individual is asked to feel a structure engraved in hard plastic, while blindfolded, and then reproduce it as closely as possible on a piece of paper (Grunwald, Ettrich, Assmann, et al., 2001). A total of three studies have utilized this task, all of which found that individuals with AN produced lower quality reproductions than control subjects (Grunwald, Ettrich, Assmann, et al., 2001; Grunwald, Ettrich, Krause, et al., 2001; Grunwald et al., 2004). Interestingly, this difference in reproduction quality seemed to be more pronounced when sunken reliefs have complex designs engraved into them (Grunwald, Ettrich, Krause, et al., 2001). Furthermore, multiple studies have demonstrated that individuals with AN produce lower quality reproductions after months of treatment and weight gain (Grunwald, Ettrich, Assmann, et al., 2001; Grunwald, Ettrich, Krause, et al., 2001; Grunwald et al., 2004). To summarize, individuals with AN exhibit an impaired ability to reproduce complex designs using haptic information even after months of treatment and gaining weight.

Another task utilized by two studies (Grunwald et al., 2002; Waldman et al., 2013) is the right parallel task. The right parallel task is a measure of haptic perception in which the participant must move a bar with one hand to make it match or be at an angle parallel to a bar in their other hand (Grunwald et al., 2002). To date only 50% of the studies using the right parallel task have found that individuals with AN perform the task more poorly than HCs when using their right hand to angle the bar (Grunwald et al., 2002). However, there are some noteworthy differences between Grunwald et al. (2002) and Waldman et al. (2013) which preclude comparisons between them. Namely, the sample of individuals with AN in Waldman et al. (2013) was comprised of individuals with AN and EDNOS-AN, whereas Grunwald et al. (2002) only included individuals who met the criteria for AN. Furthermore, Waldman et al. (2013) reported that individuals with AN spent longer reproducing the angles than HCs and that the HCs performed more poorly. These results conflict with Grunwald et al. (2002) and suggest a potential issue with the control group in Waldman et al. (2013) that still needs to be clarified.

Goldzak-Kunik et al. (2012) conducted a study that utilized a haptic object shape and size evaluation task in a sample of individuals with AN. It was found that individuals with AN did not differ from HCs when using their hands. However, they did perform poorly compared to HCs when performing an oral version of the task. Taken together with the results of Grunwald and colleagues (Grunwald, et al., 2001; Grunwald, Ettrich, Krause, et al., 2001; Grunwald et al., 2004), these results suggest that individuals with AN exhibit deficits in detecting haptic information when stimuli are complex but not simple, at least when using their hands. Furthermore, this seems to be a trait rather than a malnutrition-induced state based upon studies finding individuals with AN produce poorer quality reproductions after months of treatment and weight gain (Grunwald, Ettrich, Assmann, et al., 2001; Grunwald et al., 2004).

In general, the pattern of findings is very similar to the studies of tactile perception in AN, namely that they exhibit poorer performance on tasks involving complex stimuli than HCs. This suggests that the differences in haptic perception may have the same underlying etiology (i.e., reduced nerve innervation in the extremities) as alterations to tactile perception. This possibility is supported by studies that have found pathology of type II nerve fibers in individuals with AN (McLoughlin et al., 1998; Melchiorri & Rainoldi, 2008).

Proprioception

Proprioception refers to the sense of knowing where one’s limb/body is in space (Abboud et al., 2018). To date, only two studies have examined proprioception (with a unimodal focus) in AN; these studies were conducted by independent research groups (please see Table S8 for a detailed description of the studies included). One study conducted by Epstein and colleagues (2001) utilized two proprioception tasks: the proprioception task and the left-right orientation task.
The proprioception task entails having participants point to body parts on command, in the absence of visual information. Individuals with AN did not differ from HCs with regard to their performance on this task. The investigators also utilized a left–right orientation task in which individuals were verbally instructed to point to a specific body part using a specific hand while their eyes were either open or closed. Participants also had to perform a variant of this task, where they pointed at a specific part of the experimenter with a specific finger. Individuals with AN performed comparably to HCs on all aspects of the left–right orientation task except for when they had to point at the experimenter’s body parts (in the moderate and difficult condition) prior to treatment. Taken together, the tasks utilized by Epstein et al. (2001) suggest that individuals with AN are capable of localizing parts of their body with and without visual information, implying that proprioceptive processing is intact.

The only other study examining proprioception (with a unimodal focus) was conducted by Goldzak-Kunik et al. (2012), who used a kinesthesia task. This task entailed blindfolding the participants and having them judge the height of their hand while holding a movable vertical handle (that was randomly placed at different heights). The performance of individuals with AN did not differ from HCs—suggesting individuals with AN are capable of estimating the height of their hand.

Taken together, the results of the two studies suggest that individuals with AN are able to localize body parts on verbal command regardless of if their eyes are shut (Epstein et al., 2001) and can accurately identify the height of their hand (Goldzak-Kunik et al., 2012). However, while malnourished, individuals with AN exhibit poorer performance pointing at body parts on other peoples’ bodies (determined using the left–right orientation task; Epstein et al., 2001). In other words, the processing of proprioceptive information seems to be intact and differences exhibited on unimodal proprioceptive tasks are likely due to affective/cognitive factors.

**Interoception**

Interoception refers to sensations resulting from the viscera (see Ceunen et al., 2016, for a discussion of alternate definitions). Interoception has been the focus of 11 studies that included samples of individuals with AN. This literature has primarily utilized two types of tasks: *interoceptive accuracy* (the performance of objective tasks such as reporting heartbeat frequency) and *interoceptive sensibility* (the reporting of subjective sensations from organs). Table S9 lists studies included in this portion of the review and Table S10 provides a summary of results separated by research group. It should be noted that pain is not included in the present subsection of our review, due to evidence that it is at least partially independent of interoception (Werner et al., 2009).

*Interoceptive accuracy* is a term that refers to how accurately one is able to detect internal sensations and is usually quantified using behavioral measures (Garfinkel et al., 2016).

A widely utilized measure of interoceptive accuracy is the heartbeat detection task. The heartbeat detection task entails having the participant count the number of times their heartbeats in a given amount of time and then comparing it to the actual number of heartbeats recorded by a heart monitor (Fischer et al., 2016). A total of eight studies utilized this measure and only 37.5% (all from the same research group) found that individuals with AN detected their heartbeats less accurately than HCs (Fischer et al., 2016; Pollatos et al., 2008, 2016). Furthermore, two of the three studies found that this difference persisted over time (Fischer et al., 2016; Pollatos et al., 2016). The remaining five studies, conducted by five independent research groups, found no difference between individuals with AN and HCs (Ambrosecchia et al., 2017; Demartini et al., 2017; Eshkevari et al., 2014; Khalsa et al., 2015; Lutz et al., 2019). However, it should be noted that Khalsa and colleagues (2015) found that individuals with AN exhibited lower interoceptive accuracy than HCs only after consuming a meal (prior to it there was no difference). A single study conducted by Khalsa and colleagues (2018) utilized a heartbeat localization paradigm rather than a heartbeat detection task and found that individuals with AN exhibit differences in heartbeat localization compared to HCs, namely they exhibited a more diffuse pattern of localization (Khalsa et al., 2018). When using the detection task, it would seem that individuals with AN do not differ from HCs with regard to interoceptive accuracy. Khalsa and colleagues’ (2018) study suggests that differences exhibited may be task dependent.

It is not readily apparent why a minority of the studies (37.5%) using the heartbeat perception task found that individuals with AN exhibited lower interoceptive accuracy. As many as 80% of individuals
with AN exhibit cardiovascular abnormalities (e.g., bradycardia and reduced diastolic and systolic pressure), which are known to impact interoceptive accuracy. Namely, higher blood pressure is associated with increased interoceptive accuracy (Hassanpour et al., 2018; Mehler & Brown, 2015; Sachs et al., 2016). Of the three studies which found that individuals with AN exhibit decreased interoceptive accuracy (Fischer et al., 2016; Pollatos et al., 2008, 2016), none reported excluding participants with any type of cardiovascular pathology or reported if cardiovascular pathology was present. Of the five studies that found no difference between HCs and individuals with AN (Ambrosecchia et al., 2017; Demartini et al., 2017; Eshkevari et al., 2014; Khalsa et al., 2015; Lutz et al., 2019), two reported excluding participants due to cardiovascular disease/abnormalities and two reported excluding participants with any serious medical illness/medical illness symptoms that overlap with AN. Furthermore, one study conducted by Lutz and colleagues (2019) had a sample composed of an inpatient population, allowing them to rule out confounds such as acute food restriction. En masse, these studies suggest that differences in interoceptive accuracy may be the result of a malnutrition-induced state rather than a preexisting trait possessed by individuals with AN.

**Interoceptive sensibility** refers to subjective reports of visceral sensations (Garfinkel et al., 2016). Two different measures were used to assess interoceptive sensibility: the interoceptive attention task and the aversive breathing load paradigm. The interoceptive attention task entails having participants focus on sensations from specific organs (Kerr et al., 2016). This task was used in six manuscripts (authored by five independent research groups). Of the six studies, four (66.7%) found that individuals with AN experienced interoceptive sensations as more intense than HCs. It should be noted that these papers were produced by three independent research groups. While many of these studies found that individuals with AN exhibited elevated interoceptive sensibility, there was variability with regard to which organs individuals experienced sensations from as more intense (see Table 3 for a list of which organs).

Berner and his colleagues (2018) utilized an aversive inspiratory breathing load paradigm to compare individuals with AN to HCs. This was achieved by intermittently restricting the participants’ ability to breathe. They then had participants rate the intensity, pleasantness, and unpleasantness resulting from it. No difference was found between individuals who recovered from AN and HCs. Based upon the finding of this study in conjunction with the studies that used interoceptive attention tasks, it would seem that individuals with AN exhibit elevated interoceptive sensibility. Namely, they seem to experience sensations from their heart, bladder, stomach, and possibly lungs as more intense than HCs. The available data do not provide much with regard to whether or not this is a state or a trait. Berner and colleagues (2018) suggest that this may be a trait; however, methodological differences make it hard to compare their findings to studies that used interoceptive attention tasks in the absence of aversive breathing load.

It would seem that individuals with AN exhibit elevated interoceptive sensibility but do not differ from HCs on interoceptive accuracy tasks. However, in samples of individuals with AN who have cardiovascular (or other medical complications), it was found that they exhibit lower interoceptive accuracy than HCs. This suggests that differences in interoceptive accuracy reported in the studies may be a malnutrition-induced state rather than a preexisting trait, thus meaning it is more likely to be amenable to intervention.

### Multisensory integration

**Multisensory integration** refers to the synthesis of sensory information from two or more sensory modalities and is believed to be central to body perception (Ehrsson, 2012; Stein & Stanford, 2008). The seminal work by Stein and colleagues found that this process follows a spatial law, a temporal law, and a law of inverse effectiveness (Stein et al., 1988; Wallace et al., 1996). The spatial law dictates that response vigor of bimodal/multimodal neurons is increased by stimuli that involve different sensory modalities that occur in the same place and response is decreased if cross modal sensory stimuli are in different places.

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**Table 3.** List of studies where individuals with AN reported higher interoceptive sensibility.

| Organ               | Studies that found sensations to be more intense |
|---------------------|--------------------------------------------------|
| Bladder             | Kerr et al. (2016, 2017)                         |
| Cardiorespiratory   | Khalsa et al. (2015)                             |
| Heart               | Kerr et al. (2017)                               |
| Stomach             | Kerr et al. (2017)                               |

*This study combined sensation from the lungs and heart.*
The temporal law dictates that response of bimodal/multimodal neurons are enhanced by stimuli that occur at the same time but are degraded/unaffected by stimuli that occur at different times (Scarpina et al., 2016). The law of inverse effectiveness dictates that proportionally greater response enhancement occurs when one of the individual components of stimuli are weaker (Stein et al., 2009).

A number of studies demonstrate that individuals with AN exhibit differences in a number of tasks involving integration of the following modalities: visual–tactile–proprioceptive, visual–haptic–proprioceptive, visual–haptic–proprioceptive–vestibular, and visual–kinesthetic–proprioceptive–vestibular. Interestingly, as the focus changed from unimodal to multimodal research, the methodologies used to study these effects necessarily became more active and dynamic. The remainder of this section will be dedicated to outlining the results of these studies (see Table S11 for a detailed description of the studies included).

**Visual–tactile–proprioceptive.** A number of studies have examined tasks that involve the integration of visual, tactile, and proprioceptive information in AN. To date, the integration of the aforementioned sensory modalities has been studied through the use of the rubber hand illusion (RHI; Eshkevari et al., 2012; Keizer et al., 2014; Zopf et al., 2016) and the full body illusion (FBI; Keizer et al., 2016; Provenzano et al., 2020).

The RHI is a perceptual illusion in which one is made to feel that a fake hand is their own, when another individual brushes the fake hand and the participant’s hand in the same place at the same time (i.e., visuo-tactile synchrony) while the participant’s hand is out of sight (Botvinick & Cohen, 1998). When the brushing of the real and fake hand is asynchronous, this illusion is typically abolished. This illusion can be quantified in a number of ways including a body ownership questionnaire which asks questions about whether the fake hand felt like their own and often includes control statements to rule out response biases. Other measures of this illusion include changes in perceived hand localization before and after visuo-tactile stimulation (typically toward the fake hand; referred to as proprioceptive drift), reaching endpoint errors and decreased hand temperature (Moseley et al., 2008).

To date, three studies, conducted by three independent groups, have examined the RHI in a sample of individuals with AN. Of these, two, both conducted by independent research groups, found that individuals with AN experience the RHI more vividly than HCs (Eshkevari et al., 2012; Zopf et al., 2016). Namely, individuals with AN endorsed body ownership questionnaire items indicative of experiencing the RHI, more than HCs, regardless of whether the visuo-tactile stimulation was synchronous or asynchronous. However, they do tend to exhibit higher body ownership ratings after synchronous visuo-tactile stimulation. Notably, Eshkevari et al. (2012) found that the differences between groups were abolished when controlling for mood and Zopf et al. (2016) found individuals with AN tended to endorse control questionnaire items more than HCs. The same studies found that individuals with AN exhibit more proprioceptive drift toward the fake hand (Eshkevari et al., 2012) and more endpoint errors than HCs regardless of whether visuo-tactile stimulation was synchronous or asynchronous. However, they exhibited more endpoint errors/proprioceptive drift when stimulation was synchronous (Zopf et al., 2016).

Unlike body ownership questionnaire scores, controlling for mood did not abolish the difference between groups in Eshkevari et al. (2012). However, Eshkevari et al. also found that individuals with AN tended to perceive the location of their hand as closer to their midline than HCs in a baseline hand localization trial. The remaining study (Keizer et al., 2014) on the RHI found that individuals with AN only exhibited higher ownership scores than the HCs in the synchronous condition but did not differ with regard to proprioceptive drift. The reason for this difference is not readily apparent. However, one possible explanation for the difference is part of the study’s sample of individuals with AN was composed of individuals who no longer met the weight requirements for a diagnosis of AN, though they were reported to perform comparably. Based upon the available evidence, it would seem that individuals with AN experience the RHI more vividly than HCs.

The FBI is a perceptual illusion in which one is made to feel like a mannequin/virtual avatar’s body is their own. Like the RHI, this illusion is induced through the use of synchronous visuo-tactile stimulation. There are a number of different ways this illusion can be measured; however, the only measures used in studies that had samples of individuals with AN was body ownership questionnaires and body temperature.
(temperature drops being indicative of experiencing the illusion). Two studies, conducted by two independent groups, examined the FBI and neither found a difference between individuals with AN and HCs (Keizer et al., 2016; Provenzano et al., 2020).

Given these findings, it appears that individuals with AN experience the RHI but, not the FBI, more vividly than HCs. This is made evident by the differences between HCs and individuals with AN in studies using the RHI (note 66% found individuals with AN have a higher body ownership questionnaire score and experienced more proprioceptive drift/reaching errors; Eshkevari et al., 2012; Zopf et al., 2016) but not the FBI (Keizer et al., 2016; Provenzano et al., 2020). The exact reasons for these differences have yet to be elucidated. However, it seems affective factors are partially responsible for increased body ownership questionnaire scores, as indicated by the higher endorsement of control items by individuals with AN (Zopf et al., 2016) and the difference between groups being abolished when controlling for mood (Eshkevari et al., 2012). Furthermore, it suggests that either the spatial law of multisensory integration and/or the law of inverse effectiveness is altered in AN. This is supported by individuals with AN exhibiting more endpoint errors/proprioceptive drift than HCs regardless of visuo-tactile synchrony. Despite the aforementioned finding, they still exhibited more endpoint errors/proprioceptive drift after synchronous stimulation than after asynchronous visuo-tactile stimulation.

While the exact mechanism(s) underlying the alterations to the spatial/law of inverse effectiveness remain elusive, one potential mechanism is alterations in cardiovascular system/hand temperature. Indeed, previous research has demonstrated that experimentally altering hand temperature (Kammers et al., 2011) and experimentally altering arm blood flow (Teaford et al., in press) increase the amount of proprioceptive drift when visuo-tactile stimulation is synchronous. The aforementioned findings in conjunction with the high prevalence of cardiovascular and thermoregulation abnormalities in individuals with AN (Mehler & Brown, 2015) support this possibility.

Visual–haptic–proprioceptive. To date, there has only been one study that examined visual–haptic–proprioceptive integration in AN. This study examined whether individuals with AN exhibited differences from HCs on the size weight illusion (Case et al., 2012). The size weight illusion is a perceptual illusion in which an individual is given two objects that are identical in shape and mass but are different sizes. They are then asked to compare the two objects and determine which of the two is heavier. Normally, participants claim that the smaller object is heavier (even though it is not). Case and colleagues (2012) found that while individuals with AN did experience the SWI, they did so significantly less than the healthy control subjects.

While there is evidence that individuals with AN exhibit abnormalities in haptic perception (Grunwald, Ettrich, Krause, et al., 2001; Grunwald et al., 2004), the reason for this finding is not readily apparent. One possible explanation for this finding is that reduced information from the somatosensory system (resulting from type II nerve fiber atrophy/ischemia; McLoughlin et al., 1998) may lead to a greater amount of response enhancement (i.e., an amplification of tactile/proprioceptive information). Such a possibility is in line with the law of inverse effectiveness (see Billock & Havig, 2018) and is consistent with Case and colleagues (2012) suggestion that individuals with AN seem to rely on proprioceptive information more than HCs.

Visual–proprioceptive–vestibular. The integration of visual–proprioceptive and vestibular sensory information has been an area that has received some attention in individuals with AN (see Table S12 for a list of the studies on the topic divided by research group). Paradigms used to examine this in samples of individuals with AN include tasks that entail making body-scaled action judgments (the aperture task and the hoop task) and a collision judgment task. It should be noted that the hoop task involved stepping through the hoop one chose; we however did not include it in “Visual–kinesthetic–proprioceptive–vestibular” section because motion capture was not used.

To date, four studies, conducted by two independent groups, have utilized body-scaled action judgment tasks. One of the most extensively studied body-scaled action judgment tasks is called the aperture task. The aperture task entails having participants make judgments about whether they can pass through openings of varying widths. This is then used to compute a passability ratio (a ratio of shoulder width to aperture width). To date, three studies, conducted by the same group, have utilized the aperture task, all of which found that individuals with AN exhibited a higher passability ratio than HCs (Guardia et al., 2010; Guardia, Conversy, et al., 2012; Metral et al.,
In other words, the aperture width had to be significantly larger for them to think they could pass through it. However, individuals with AN can accurately judge whether other individuals can pass through an aperture (Guardia, Conversy, et al., 2012). Keizer and colleagues (2019) utilized a similar task, called the hoop task, which entailed individuals making judgments about the smallest hula hoop they could step through. Like the studies using the aperture task, it was found that individuals with AN overestimated the smallest opening they could pass through. In other words, it would seem that individuals with AN experience their body as wider than it actually is.

One study, conducted by Nico and colleagues (2010), utilized a collision avoidance task. This entailed having individuals with AN make judgments about whether a robotic arm would hit them if it continued on its current trajectory. It was found that individuals with AN were significantly less accurate when asked to make judgments about it hitting the left side of their head or their left shoulder (Nico et al., 2010). Taken together, these studies suggest that individuals with AN experience their body as larger than it actually is. Based upon the available data, this difference in perceived size seems to be more pronounced in (or only present in) the more lateral portions of the body (i.e., shoulders and hips). Interestingly, while they cannot accurately judge their own passability (determined using the aperture task and hoop task), individuals with AN can accurately judge other individuals passability (Guardia, Conversy, et al., 2012). This suggests that the difference in passability ratio of individuals with AN is not due to visual differences.

To date, only Keizer et al. (2019) has examined visual–proprioceptive–vestibular integration over time. Their study revealed that individuals with AN still overestimated the smallest opening they could pass through, relative to HCs, after treatment (though hoop training was found to make this difference less pronounced). Based upon this finding, it would seem that experiencing one’s body as wider could be a trait.

Visual–haptic–proprioceptive–vestibular. To date, two studies (conducted by the same research group) have examined the integration of visual–haptic–proprioceptive and vestibular information in AN, both of which used the subjective vertical (SV) task. The SV task involves having participants adjust a metal rod to match what they feel is vertical (Guardia, Cottencin, et al., 2012). It has been found that individuals exhibit slight deviations in SV judgments, both toward their head axis (A effects) and away from their head axis (E effect; Guardia, Cottencin, et al., 2012). These effects can become even more pronounced in populations with different types of sensory pathology (e.g., vestibular dysfunction). Both of the studies on individuals with AN found they did not differ from HCs when supine; however, they exhibited significantly more pronounced A effects (i.e., moving the bar toward their head axis) than HCs when laying on their side (regardless of which side; Guardia, Cottencin, et al., 2012; Guardia et al., 2013). Furthermore, this difference does not seem to be the result of a unimodal abnormality in visual or (simple) haptic discrimination (Guardia et al., 2013).

The findings of these studies suggest that individuals with AN exhibit abnormalities in multisensory integration. Guardia and colleagues (2013) suggest that these differences may be due to reduced input from the somatosensory system. Based upon the research presented in the present article, this appears to be a likely candidate mechanism.

Visual–kinesthetic–proprioceptive–vestibular. Two studies have examined the integration of visual–kinesthetic–proprioceptive and vestibular information in a sample of individuals with AN (both were conducted by separate groups). Both of these studies used the aperture task; however, the noteworthy difference from the studies discussed in “Visual–proprioceptive–vestibular” section is that these studies involved actually crossing through the aperture while using motion capture. Not only did individuals with AN have a significantly higher passability ratio (i.e., had a significantly larger shoulder width to aperture width ratio to pass through without rotating their shoulders), they moved in a way consistent with the research on passability judgments detailed in “Visual–proprioceptive–vestibular” section (Keizer et al., 2013; Metral et al., 2014). In other words, individuals with AN moved in a manner consistent with having a body wider than it actually was. It is not readily apparent if this difference is a state or trait and mandates further study.

Summary of multisensory integration studies. In aggregate, the studies discussed in “Multisensory integration” section suggest that multisensory integration is abnormal in AN. This is consistent with Gaudio and colleagues (2014) claim that multisensory integration is impaired in AN. In other words, sensory modalities are not merged together (or are merged
differently than HCs). However, understanding of the mechanism(s) underlying abnormal multisensory integration in AN is lacking. Reduced input from the somatosensory system may underlie the differences exhibited by individuals with AN.

Summary of findings
Throughout the course of third section of this article, we have outlined the findings of studies on individuals with AN that used unimodal and multisensory tasks. Based upon the evidence presented, it seems that individuals with AN exhibit abnormalities on tasks involving affective touch, haptic perception, interoception, nociception, tactile perception, and multisensory integration. Namely, it has been found that they find affective touch less pleasant, exhibit poor performance on tactile/haptic discrimination tasks, exhibit higher pain thresholds (when thermal stimuli are involved), exhibit elevated interoceptive awareness, and experience multisensory illusions more or less vividly than HCs. Many of the differences exhibited by individuals with AN are likely, at least partially, the result of cascades of malnutrition induced (state-dependent) changes to the body.

Conclusion and future directions
We have outlined the research on somatosensory submodalities in AN. The available data indicate that individuals with AN exhibit a reduced ability to discriminate (but not detect) complex haptic and tactile stimuli, an elevated thermal pain threshold, and altered multisensory integration while symptomatic. Furthermore, based upon the existing data, these differences seem to be confined to the extremities and lateral portion of the trunk. However, in many cases, it would seem that differences between individuals with AN and HCs do not persist after recovery. The remainder of the present section will be dedicated to identifying gaps within the literature and future directions for this area of research.

Gaps and future directions
There remain a number of gaps in our knowledge of the somatosensory system in AN. In this section of the article, we will reiterate the gaps identified in the third section and make suggestions for ways they can be addressed. We will also make general methodological and demographic reporting suggestions that could aid in our ability to fill in these gaps.

Prior to discussing gaps in our understanding of specific submodalities, we will outline gaps that span multiple submodalities. Among these gaps are whether differences exhibited by individuals with AN are a state or trait and whether these differences are confined to the extremities.

One of the largest gaps is our lack of understanding of whether the differences exhibited by individuals with AN are a state or trait. The available evidence would seem to suggest that some differences are a state (i.e., nociception, affective touch, and interoception), whereas others seem to be a trait (i.e., tactile and haptic perception), and in some cases, there is no evidence to suggest either. Many of the studies that examined whether differences persist after recovery compared separate groups rather than utilizing longitudinal designs. While we appreciate the difficulty inherent in conducting longitudinal studies, they will be valuable to our understanding of how differences in somatosensory submodalities/multisensory integration change over time.

It also remains to be determined whether differences exhibited by individuals with AN are confined to the extremities/the lateral portion of the trunk. The available evidence suggests that the differences are confined to the aforementioned regions; however, very few studies have examined other regions. Therefore, it will be important for future studies to examine multiple regions of the body. Ideally, regions known to have high (e.g., thighs) and low affective valence (e.g., upper back).

Nociception. Nociception is one of the most widely studied sensory modalities in AN. As reviewed above, it would seem that individuals with AN exhibit elevated thermal pain thresholds that normalize after recovery. However, many questions remain. One of which is what are the mechanisms underlying the elevated thermal pain threshold exhibited by individuals with AN. As reviewed above, there is evidence suggesting that skin temperature and hormone levels are associated with this difference. Therefore, we recommend studies examine multiple physiological measures (i.e., look at skin temperature and hormone levels) to better characterize the relation between physiological differences and thermal pain thresholds in AN.

Affective touch. The available evidence, reviewed in “Affective touch” section, suggests that individuals with AN experience positive affective touch as less pleasant than HCs until after they recover. After
recovery, this difference becomes less pronounced. This difference does not seem to be impacted by social stimuli—thus suggesting that it is the result of bottom-up changes. However, there remains a number of open questions—including whether individuals with AN experience affective touch in body regions besides the forearm/hand as less pleasant. Furthermore, it is not clear whether this difference would persist if stimuli were more ecologically valid. For example, having the individual’s significant other be in charge of administering the pleasant affective touch stimuli. It will also be important to gain a better understanding of changes in peripheral physiology associated with this difference. For example, do individuals with AN exhibit differences with regard to the density of CT nerve innervation or CT nerve excitability?

**Tactile and haptic perception.** The available evidence suggests that individuals with AN exhibit poorer performance on tasks that involve discriminating tactile/haptic stimuli but not tasks that involve detecting them. It would seem that these differences persist after recovery, suggesting the possibility that this is a preexisting trait. However, there remain a number of unanswered questions including whether differences in tactile and haptic discrimination co-occur. Therefore, we recommend studies examine both haptic and tactile tasks; this should include tasks that measure detection as well as discrimination. Furthermore, the discrimination tasks should differentiate between simple and complex stimuli.

It will also be important to better understand the etiology of the differences exhibited by individuals with AN. As stated above, individuals with AN have been found to exhibit slower nerve conduction velocity and nerve atrophy in a region that other studies found to be associated with differences in tactile discrimination. This suggests that reduced nerve innervation may at least be partially responsible for differences exhibited by individuals with AN. Studies that look at tactile and haptic discrimination prior to tissue biopsies taken from the region are recommended.

**Interoception.** Based upon the evidence outlined above, it would seem that individuals with AN exhibited elevated interoceptive sensibility and comparable interoceptive accuracy compared to HCs. However, the relationship between interoceptive sensibility and accuracy remains to be fully explored. The only measures of interoceptive accuracy we are aware of entailed the heart. This is noteworthy because individuals with AN are known to exhibit cardiovascular pathology (e.g., bradycardia) and blood pressure is known to impact interoceptive accuracy. Therefore, it would be beneficial to examine interoceptive accuracy in individuals who have AN and either do or do not exhibit cardiovascular pathology. Furthermore, it would be beneficial to examine interoceptive sensibility in multiple organs. Such studies would not only provide a better understanding of the relationship between interoceptive sensibility and awareness, but would also provide us with a better understanding of whether the cardiovascular system is related to sensation in other organs.

**Multisensory integration.** A number of studies have examined multisensory integration in AN. The vast majority of which revealed that individuals with AN exhibited differences in multisensory integration. However, it remains unclear what aspect of multisensory integration is actually altered. As stated above, individuals with AN experience the RHI as more vivid than HCs regardless of visuo-tactile stimulation synchrony (Eshkevari et al., 2012; Zopf et al., 2016). It would appear that they still experience the illusion as more vivid when visuo-tactile stimulation is synchronous than when it is asynchronous. Taken together, this suggests that either the spatial law of multisensory integration is altered or reduced input from the somatosensory system leads to an amplification of the sensory information (such an event is consistent with the law of inverse effectiveness). There are a number of different ways in which these possibilities could be narrowed down. One possibility is comparing the experience of individuals with AN to HCs on a variant of the RHI where the distance between the real and fake hand is systematically varied. If the differences exhibited by individuals with AN are the result of an altered spatial law of multisensory integration, one would expect to see individuals with AN experience the RHI with larger distances between the real and fake hand than HCs. Another possibility would be to use functional neuroimaging to compare visuo-tactile and visuo-haptic integration in individuals with AN and HCs. If the differences exhibited by individuals with AN are the result of the law of inverse effectiveness, one would expect to see greater response enhancement in individuals with AN (see Kim et al., 2012, for an example of a study that utilized functional neuroimaging to study the law of inverse effectiveness).
Another potential means of addressing this question is through the use of animal studies. Indeed, the work of Wada and colleagues (2016) suggests that a variant of the RHI called the rubber tail illusion can be induced in rodents. Such a paradigm would allow a finer grain analysis than possible with human subjects. Namely, the investigator could vary the distance between the real and fake tail as well as the amount of afferent information coming from the tail (via surgical and/or electrophysiological means). There is a complete absence of animal models aimed at understanding the sensory consequences of AN; this is unfortunate because a number of animal models have been developed to study other aspects of AN and resulted in an enhanced understanding of the symptoms (see Avena, 2013, for an extensive treatment of animal models of eating disorders).

It also remains to be seen if individuals with AN exhibit differences in sensorimotor adaptation. As reviewed above, individuals with AN exhibit movements consistent with them experiencing their body as larger than it actually is. If this is indeed the case, then there will also likely be quantitative differences on sensorimotor adaptation tasks. See Smart et al. (2020) for examples of tasks that examine sensorimotor adaptation.

Reporting and methodological recommendations. The study of the somatosensory system in AN is still in its infancy. However, our understanding of the available data is limited by methodological and demographic reporting differences. Therefore, we put forth the following recommendations. (1) Studies examining somatosensory submodalities/multisensory integration in AN should include measures of affect, namely measures of anxiety and depression, both of which are known to be associated with differences in sensitivity to sensations. (2) Studies that combine samples of individuals with AN and individuals who no longer meet the weight requirements for AN (often referred to as EDNOS-AN) should report the results of the individuals with EDNOS-AN and AN separately (even if it’s in a supplemental document). Doing this will allow for a better understanding of whether differences truly persist after weight restoration. (3) More detailed descriptions of samples of individuals with AN are needed to better be able to understand differences across studies. We recommend reporting the following: the mean age of onset, mean age at time of study, lowest BMI, and current BMI. Furthermore, we recommend separating the demographic information for individuals with AN and EDNOS-AN. Doing this would facilitate a better understanding of differences between samples and may also help shed light on whether the onset of AN at certain points in development is associated with more differences than other time points.

Conclusion
The aim of the present scoping review was to (1) summarize what is known about somatosensory submodalities in AN, based upon the available data, (2) identify gaps within the literature, and (3) suggest future avenues of research. The reviewed research suggests that individuals with AN experience positive affective touch as less pleasant, exhibit poor performance on tactile/haptic discrimination tasks, exhibit higher thermal pain thresholds, exhibit elevated interoceptive awareness, and experience multisensory illusions more or less vividly than HCs. However, knowledge of the physiological correlates and how the aforementioned differences change over time is lacking. We suggest the use of longitudinal studies that utilize physiological measures in conjunction with behavioral tasks. Furthermore, it is also of interest to determine whether sensory/multisensory abnormalities in AN are confined to the extremities or are also present in other regions (i.e., the trunk and head). Determining this would allow the development of more targeted interventions for sensory-related symptoms of AN as well as a better understanding of the underlying etiology.

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Supplemental Material
Supplemental material for this article is available online.
Note

1. It should be noted that affective touch can also be elicited via deep pressure (Case et al., in press) and temperature (Rolls et al., 2009). To date, no studies have examined the impact of these types of affective stimuli in individuals with anorexia nervosa.

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