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# The Dutch Glasgow Sensory Questionnaire: Psychometric properties of an autism-specific sensory sensitivity measure

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## Abstract

Sensory sensitivity is common in autistic people and since the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.), hypo- and hyper-responsiveness to sensory stimuli are part of one of the criteria domains for an autism spectrum disorder classification. For scientific research and the clinical practice, one needs reliable and valid questionnaires that measure sensory sensitivity and can distinguish between hypo- and hyper-responsiveness. We translated the Glasgow Sensory Questionnaire into Dutch. The aim was to examine the psychometric properties and the clinical use of the Dutch Glasgow Sensory Questionnaire in 78 autistic and 68 typically developing adults (18–45 years; IQ > 70). Just like the original Glasgow Sensory Questionnaire, the Dutch Glasgow Sensory Questionnaire is a reliable and valid questionnaire. The Dutch Glasgow Sensory Questionnaire had reliable hypo- and hyper-responsiveness subscales, reasonable to good modality subscales and was stable over time. Moreover, using the 95th percentile of the typically developing group as cut-off, we showed that two thirds of the autistic adults had heightened sensory sensitivity. We also showed that hypo- and hyper-responsiveness do co-exist in both autistic and typically developing adults. In sum, we conclude that the Dutch Glasgow Sensory Questionnaire is suitable to be used in scientific research as well as in the clinical practice.

## Keywords

autism, Glasgow Sensory Questionnaire, sensory sensitivity.

Sensory sensitivity is common in people with an autism spectrum disorder (ASD) diagnosis. ASD is traditionally characterized by social and communication difficulties and repetitive behaviors (American Psychiatric Association (APA), 2000, 2013). However, in the latest *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM-V), sensory sensitivity has become part of the diagnostic criteria for ASD (APA, 2013). Both hypo- and hyper-responses to sensory stimuli to any sensory modality as well as sensory seeking behavior are part of these criteria. Sensory sensitivity can affect both social interaction abilities and repetitive behaviors (e.g. Deschrijver et al., 2017; for review, see Jiujiu et al., 2007), which suggests that sensory sensitivity influences other ASD-related symptoms. For both scientific research and clinical practice, reliable and valid questionnaires regarding sensory sensitivity that can also distinguish between hypo- and hyper-responsiveness are necessary. Hence, in this article, we will focus on a potentially clinically useful sensory sensitivity measure, the Glasgow Sensory Questionnaire (GSQ; Robertson and Simmons, 2013).

So far, the majority of researchers and clinicians seem to use the *Adult/Adolescent Sensory Profile* (AASP; Brown and Dunn, 2002) as sensory sensitivity questionnaire in autistic adults. Although the AASP creates a sensory profile for each individual, it is not designed to provide specific information on hyper- or hypo-sensitivity. There is a relatively new sensory sensitivity questionnaire (i.e. GSQ; Robertson and Simmons, 2013) that, contrary to the AASP, is specifically designed for autistic adults. The GSQ is a 42-item sensory sensitivity self-report questionnaire that receives more and more international scientific attention (e.g. Horder et al., 2014; Sapey-Triomphe et al., 2017; Takayama et al., 2014; Ward et al., 2017). The items cover

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seven modalities (i.e. visual, auditory, gustatory, olfactory, tactile, vestibular, and proprioception). Each modality is represented by six items, three hypo-, and three hyper-sensitivity-related items. For example, a hyper-sensitivity item in the modality auditory is “do you dislike loud noises?”, while a hypo-sensitivity item in the same domain is “Do you really like listening to certain sounds (for example, the sound of paper rustling)?”. The items refer to one’s behavior to certain sensory stimuli or certain sensory preferences. Each item can be scored on a 5-point scale (never, rarely, sometimes, often, and always), with scores ranging from 0 to 4 and a possible total score range of 0–168. The GSQ provides a total score, a score for each modality, a hypo- and hyper-responsiveness score per modality, as well as a total hypo- and hyper-responsiveness. Hence, this ensures both an impression of the overall sensory sensitivity level and allows for examining which specific modalities are affected and how (i.e. hypo- or hyper-responsiveness).

Besides the GSQ, another sensory sensitivity questionnaire which has recently been developed is the *Sensory Perception Quotient* (SPQ; Tavassoli et al., 2014). Contrary to the GSQ, the SPQ specifically focuses on sensory perception and only includes five out of seven modalities included in the GSQ. Yet another measure is the *Sensory Sensitivity Questionnaire* (SSQ; Minshew and Hobson, 2008). Similar to the GSQ, the SSQ is specifically designed for autistic adults, but it is developed for a quick screening. It consists of only 13 items and the answer possibilities are limited (i.e. yes or no). Moreover, like the AASP, one cannot make a distinction between hypo- and hyper-sensitivities on each sensory modality. In sum, the GSQ (Robertson and Simmons, 2013) seems clinically the most interesting measure as it is (1) specifically developed for autistic adults and (2) distinguishes between hypo- and hyper-sensitivities among seven sensory modalities.

Studies that have examined some psychometric properties of the original GSQ have shown that it is a reliable and valid questionnaire. The internal consistency seems excellent ( $\alpha=0.94$ ; Robertson and Simmons, 2013). Also, the convergent and divergent validity has been shown to be good as it has a strong correlation with other sensory questionnaires such as the AASP ( $r=0.72$ ; Horder et al., 2014) and much weaker correlations with questionnaires measuring other constructs such as anxiety (Spielberger Trait Anxiety Inventory (STAI);  $r=0.42$ ; Horder et al., 2014). It is also positively related to autism traits, measured with the Autism Quotient (AQ; Baron-Cohen et al., 2001) in autistic adults ( $r=0.53$ ; Horder et al., 2014) and typically developing (TD) adults ( $r=0.78$ ; Robertson and Simmons, 2013). Due to these good psychometric properties, the original GSQ is already translated into Japanese (Takayama et al., 2014) and French (Sapey-Triomphe et al., 2017). The internal consistency of the Japanese GSQ ( $\alpha=0.93$ ; ASD group) and the French GSQ ( $\alpha=0.95$ ; mixed ASD and TD group) was similar to the original GSQ. In both

translations, the convergent and divergent validity has, unfortunately, not been examined. Taken together, this suggests that the GSQ is indeed a reliable and valid measure. However, in none of these former studies the test-retest reliability has been tested. This is unfortunate as knowing the stability of an assessment instrument is of importance for, for example, determining change across the lifespan or due to a specific intervention. Therefore, in this study, we will focus on examining the internal consistency, the convergent and divergent validity, as well as the test-retest reliability of the Dutch version of the GSQ (GSQ-NL).

Besides the usual psychometric analyses, Sapey-Triomphe et al. (2017) performed a factor analysis on the French GSQ to determine whether the GSQ had indeed seven factors (e.g. seven modalities) or two factors (e.g. hypo- and hyper-sensitivity). Based on a combined ASD and TD sample, the French GSQ had a two-factor structure that corresponded with the distinction between hypo- and hyper-sensitivities. Moreover, by creating a low and high autistic traits group based on the AQ cut-off score, they tested the often-reported relationship between autistic traits and sensory sensitivity (e.g. Horder et al., 2014; Robertson and Simmons, 2012; Takayama et al., 2014). As they observed that hypo- and hyper-sensitivity scores across the seven modalities on the French GSQ showed stronger inter-correlations within the high AQ group than in the low AQ group, they concluded that people with many autistic traits were more likely to experience hypo- and hyper-sensitivity within the same sensory modality on several modalities. People with few autistic traits were more likely to have either hypo- or hyper-sensitivity to a single modality (Sapey-Triomphe et al., 2017). These findings are in line with what some autistic people report (Elwin et al., 2012). So, to be able to provide more insight into the relationship between hypo- and hyper-sensitivities in autistic adults, we will examine (using the method of Sapey-Triomphe et al., 2017) whether autistic adults are more likely to have both hypo- and hyper-sensitivities within the same modality compared to a TD group.

All studies discussed so far have examined the properties of the GSQ on a group level. However, in clinical practice, we see individuals who often differ greatly from each other in both the type and severity of their sensory sensitivity. In a diagnostic trajectory, determining the severity level of an individual’s sensory sensitivities is necessary to make informed decisions on, for example, future interventions. Therefore, we will calculate the 95th percentile of the TD group to provide a cut-off score that indicates heightened sensory sensitivity levels and report the percentage of autistic adults reporting heightened sensory sensitivities (for similar methods, see, for example, Geurts et al., 2014; Lever and Geurts, 2016; Nigg et al., 2005). Moreover, when an individual patient does receive treatment for their sensory sensitivities, one might want to

monitor possible change. A post-treatment score will often be slightly different from the pre-treatment score due to random variation. To determine whether the change in scores between pre- and post-treatment is a reliable and significant change, one uses the Reliable Change Index (RCI; Jacobson and Truax, 1991). We will report the RCI needed to label a score change as an actual significant chance. Moreover, we will provide the information needed for clinicians to calculate such an RCI.

In sum, this study has the following aims: (1) to test whether we can replicate the internal consistency of the original GSQ, including the GSQ subscales; (2) to examine the test–retest reliability; (3) to replicate the convergent and divergent validity of the original GSQ; (4) to test whether we can observe a similar hypo- and hyper-sensitivity finding as Sapey-Triomphe et al. (2017) in a clinical ASD and a TD group; and (5) to examine additional, clinically relevant, features of the GSQ-NL (i.e. the 95th percentile TD cut-off and the RCI).

## Methods

### Participants

In total, 147 adults (79 ASD; 68 TD) participated. The autistic participants were recruited via a specialized clinical center for autistic people as well as via websites of Dutch societies for autistic people. The control participants were recruited to match the autistic participants on age, IQ, and gender as much as possible and were recruited from the general population via the personal network of the researchers and master students involved. All participants gave written informed consents. The study was approved by the ethical comity of the University of Amsterdam (2014-BC-3773; 2016-BC-7146).

Inclusion criteria for the ASD group were as follows: (1) having a *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; DSM-IV; APA, 2000) or DSM-V (APA, 2013) autism diagnosis (i.e. Asperger syndrome, pervasive developmental disorder not otherwise specified (PDD-NOS), autism, or ASD) prior to inclusion, which needed to be determined by a clinician specialized in autism and (2) having a score above the cut-off of 54 on the Social Responsiveness Scale for Adults (SRS-A; Constantino and Gruber, 2005; Dutch version: De la Marche et al., 2009) or score above the cut-off of 26 on the AQ (Woodbury-Smith et al., 2005; Dutch version: Hoekstra et al., 2008). The Autism Diagnostic Observation Schedule 2 (ADOS 2; Lord et al., 2012), module 4, was administered to 73.4% of the ASD participants (n=58) in order to describe the autism symptoms of the ASD group.

For the TD group, the inclusion criteria were as follows: (1) not having (a suspicion of) a psychiatric or developmental disorder; (2) not having a direct family member with ASD or a psychotic disorder; (3) having a score below

the cut-off of 54 on the SRS-A and having a score below the cut-off of 26 on the AQ; and (4) no psychotropic medication use.

Both groups needed to have (1) an IQ above 70, indicated by either the abbreviated Wechsler Adult Intelligence Scale IV (WAIS-IV; i.e. Matrix Reasoning and Vocabulary; Uterwijk, 2000) or education level (high school or higher) and (2) an age between 18 and 45 years old.

### Materials

**The GSQ.** In agreement with the original authors (Robertson and Simmons, University of Glasgow), we translated the GSQ into Dutch (GSQ-NL). The GSQ-NL was kept in the original format, with the same answer possibilities. The GSQ-NL was then translated back into English by an independent person, who was not involved in this study and who had not seen the original GSQ. This back-translation was sent to Robertson and Simmons for their approval. After receiving this approval, the data collection started.

**Convergent validity.** To determine whether the GSQ has good convergent validity, its scores were compared to the AASP (Brown and Dunn, 2002; Dutch version: Rietman, 2007) and the SSQ scores (Minshew and Hobson, 2008; Dutch version: Lever and Geurts, 2013). The AASP is a sensory sensitivity self-report questionnaire with 60 items, which are scored on a 5-point scale (almost never, seldom, occasionally, frequently, and almost always; scored 1–5, respectively). This questionnaire results in four quadrants (“Low registration,” “Sensory Sensitivity,” “Sensation Seeking,” and “Sensation Avoiding”), which correspond to four patterns of responding to sensory stimulation (Brown and Dunn, 2002). Internal consistency for each quadrant lies between  $\alpha=0.64$  and  $\alpha=0.70$  for adults (Rietman, 2007). Besides these four quadrants, we also used a total score (possible scores ranging from 60 to 300; for similar method, see Horder et al., 2014).

The SSQ consists of 13 statements about sensory sensitivity with two answer possibilities (yes or no), which are given a score of 1 or 0, respectively (maximum score of 13). In this study, we used the total score, which has been shown to be reliable ( $\alpha=0.77$ ; Lever and Geurts, 2013).

**Divergent validity.** To determine the divergent validity of the GSQ, we correlated the GSQ scores with measures of two other constructs, namely, social skills and general cognitive ability. The “Inventory of Interpersonal Situations” (IIS; Van Dam-Baggen and Kraaimaat, 1999) is a self-report questionnaire that was used to measure social skills. The IIS consists of two 35-item scales: (1) a frequency scale (how much a person engages in certain social situations) and (2) an anxiety scale (a person’s level of tension in these social situations). The total score of the frequency scale is used to measure social skills as has been done

previously (e.g. Jansen et al., 2006; Smeekens et al., 2015). A higher score on the frequency scale represents better social skills. Convergent validity of this scale is modest ( $r = -0.44$  with the social inadequacy subscale of the Symptom Check List-90 (Arrindell and Ettema, 1981;  $p < 0.01$ ; Van Dam-Baggen and Kraaimaat, 1999). The internal consistency is good ( $\alpha = 0.93$  in psychiatric patients and  $\alpha = 0.91$  in TD; Van Dam-Baggen and Kraaimaat, 1987). General cognitive ability (i.e. total IQ) was tested with the aforementioned abbreviated WAIS-IV (i.e. subtests Matrix Reasoning and Vocabulary).

**Procedure.** All participants were recruited for two different experimental studies in which more data were collected than described in this article. The data that are not described in this article can be found in one published (Kuiper et al., 2017) and one submitted paper (Kuiper et al., under review). The participants were asked to fill out a series of questionnaires, which they received at their home address, prior to a testing session (as part of the experimental studies). The filled-in questionnaires were handed in at the test session. Approximately, 12 weeks after testing, participants received the same questionnaires again and returned these by mail. They received €10–€15 for participating and up to €20 for travel expenses. All participants received a study report by mail.

**Missing data.** On the questionnaires, a maximum of 10% missing data were accepted. In case of fewer missings, the missing data points were replaced by the mean of the data points in that particular (sub)scale. For the GSQ total score, one ASD participant had more than 10% missings and was, therefore, excluded from all analyses. For the AASP total score and AASP quadrant Sensory Avoiding, one ASD participant had more than 10% missings and analyses using these variables were performed without this participant.

### Statistical analyses

With one-way analysis of variance (ANOVA), we analyzed potential group differences on the following descriptives: age, total intelligence quotient (TIQ), AQ (log-transformed), SRS-A, GSQ total score, GSQ subscales, AASP total score, and IIS frequency scale (log-transformed). Transformation of certain variables was required to achieve a normal distribution. As this was not feasible for the SSQ, we used a Mann–Whitney test to examine possible group differences. We used a Bonferroni correction to statistically correct for the multiple comparisons.

The following analyses were run within each group separately. To examine the internal consistency of the GSQ-NL, we calculated Cronbach's  $\alpha$  for the total GSQ (42 items), for the seven GSQ modalities (6 items each) as well as the hypo- and hyper-responsiveness scales (21 items each).

Test–retest reliability was examined using Pearson's correlation (GSQ total score with GSQ total score follow-up). We used a square root transformation to normalize the data of the GSQ follow-up, and in order to calculate the test–retest reliability we, therefore, also used transformed GSQ scores. Convergent validity was examined using Pearson's (GSQ with AASP) and Spearman correlations (GSQ with SSQ). Divergent validity was examined using Pearson's correlations (GSQ with IIS (log-transformed); GSQ with TIQ). The divergent validity correlations were expected to be lower than the convergent validity correlations. This was tested with Fisher's  $r$ -to- $z$  transformations.

We used similar analyses as Sapey-Triomphe et al. (2017) to examine the relationship between the hypo- and hyper-sensitivity scores. We used Pearson's correlations to examine the relationship between the total hypo- and hyper-sensitivity scores and Spearman correlations to examine the relationship between the hypo- and hyper-sensitivity scores of each modality. We used Fisher's  $r$ -to- $z$  transformation to compare the correlation coefficients between the groups (ASD vs TD). We used R (Corrplot and ColorRamps packages) to build a color matrix similar to Sapey-Triomphe et al. (2017) for better comparison. We also compared the ASD color matrix with the TD group's color matrix, using Steiger test (Steiger, 1980; "psych" R package).

The RCI (Jacobson and Truax, 1991) was used to calculate how many points one has to change on the GSQ for it to be a reliable difference. We used the formula:  $RCI = 1.96 * SE$ . SE is the standard error of the GSQ, which can be calculated by the following formula:  $SE = SD \sqrt{2(1 - r_{xx})}$ . SD is the standard deviation of the GSQ in total (i.e. 23.8) and the reliability measure ( $r_{xx}$ ) was indicated by the test–retest reliability coefficient. To calculate the RCI, one individual uses the following formula:  $RCI = (\text{prior score} - \text{post score}) / SE \sqrt{2}$  (Van Yperen and Veerman, 2008). The prior score is the total score of the first time the GSQ was administered, post score is the total score of the second time the GSQ was administered, and SE is the standard error of the GSQ (the SE of the GSQ-NL is 8.91). If the RCI score lies above 1.96 or below  $-1.96$  (or 1.65 and  $-1.65$  in the clinical practice; Van Yperen and Veerman, 2008), it means that one reports significantly less or more sensory sensitivity, respectively. Finally, we calculated the 95th percentile of the total GSQ score of the TD group and examined how many autistic adults had a score above that percentile.

We used the program Statcheck (Epskamp and Nuijten, 2016) to check whether we reported all  $p$  values correctly.

## Results

### Group differences

As intended with our inclusion criteria, the ASD group reported significantly more ASD symptoms on the AQ and

**Table 1.** Group descriptives and statistics.

|              |        | ASD<br>(n = 78) | TD<br>(n = 68) | p value | Cohen's d |
|--------------|--------|-----------------|----------------|---------|-----------|
| Descriptives | Gender | 49M; 29F        | 53M; 15F       | 0.05    | –         |
|              | Age    | 33.81 (6.5)     | 31.59 (6.6)    | 0.04    | –0.34     |
|              | TIQ    | 104.25 (17.3)   | 102.81 (16.1)  | 0.63    | –0.09     |
|              | SRS-A  | 94.85 (22.3)    | 24.31 (12.3)   | 0.00*** | –3.85     |
|              | AQ     | 35.01 (6.7)     | 11.2 (5.0)     | 0.00*** | –3.99     |
| ADOS         |        | ASD<br>(n = 57) |                |         |           |
|              | SA     | 7.58 (4.0)      |                |         |           |
|              | RRB    | 1.21 (1.3)      |                |         |           |
|              | Total  | 8.79 (4.8)      |                |         |           |

AASP: adult adolescent sensory profile; ADOS-2 (mod. 4): Autism Diagnostic Observation Schedule 2 module 4 total score ( $\geq 8$  classifies as autism spectrum; Hus and Lord, 2014); ADOS SA: social affect; ADOS RRB: restricted repetitive behavior; age is in years; ASD: autism spectrum disorder; AQ: Autism Quotient; Cohen's d: effect size (small = 0.20; medium = 0.50; large = 0.80); F: female; M: man; SRS-A: Social Responsiveness Scale for Adults; TD: typically developing; TIQ: total intelligence quotient.

The numbers in the ASD and TD column are mean (standard deviation).

Bonferroni correction:  $0.05/4 = 0.01$ . So, p values below 0.01 are considered significant.

\*\*\* $p \leq 0.001$ .

**Table 2.** Questionnaire data and statistics.

|      |                | ASD<br>(n = 78) | TD<br>(n = 68) | p value | Cohen's d |
|------|----------------|-----------------|----------------|---------|-----------|
| GSQ  | Visual         | 9.99 (4.1)      | 4.68 (2.9)     | 0.00*** | –1.48     |
|      | Auditory       | 14.62 (3.6)     | 8.63 (3.4)     | 0.00*** | –1.71     |
|      | Gustatory      | 8.39 (3.5)      | 4.96 (3.0)     | 0.00*** | –1.05     |
|      | Olfactory      | 7.89 (3.5)      | 4.81 (2.4)     | 0.00*** | –1.02     |
|      | Tactile        | 9.05 (3.6)      | 4.37 (2.6)     | 0.00*** | –1.47     |
|      | Vestibular     | 7.10 (4.1)      | 2.90 (2.2)     | 0.00*** | –1.25     |
|      | Proprioception | 7.68 (4.1)      | 3.00 (2.2)     | 0.00*** | –1.40     |
|      | Hypo total     | 28.46 (10.7)    | 16.18 (7.5)    | 0.00*** | –1.31     |
|      | Hyper total    | 36.49 (12.2)    | 17.35 (8.1)    | 0.00*** | –1.82     |
|      | Total          | 64.95 (20.5)    | 33.53 (14.5)   | 0.00*** | –1.75     |
| SSQ  | Total          | 6.82 (2.9)      | 2.06 (1.6)     | 0.00*** | –2.00     |
| IIS  | Frequency      | 94.94 (11.1)    | 118.67 (17.1)  | 0.00*** | 1.67      |
|      |                | ASD<br>(n = 77) | TD<br>(n = 68) | p value | Cohen's d |
| AASP | Total          | 167.38 (25.0)   | 131.51 (18.4)  | 0.00*** | –1.62     |

AASP: adult adolescent sensory profile; ASD: autism spectrum disorder; TD: typically developing; GSQ: Glasgow Sensory Questionnaire; SSQ: Sensory Sensitivity Questionnaire; IIS: Inventory of Interpersonal Situations.

SRS-A than the TD group (see Table 1). We observed no statistically significant differences between the two groups on age, gender, and IQ.

As expected, the ASD group scored significantly higher on the three sensory sensitivity questionnaires (see Table 2) than the TD group, meaning that autistic adults reported more sensory sensitivities on all modalities. Also as expected, the ASD group scored significantly lower on the social skills questionnaire (IIS) than the TD group.

### Reliability and test–retest reliability

The total GSQ had an excellent Cronbach's  $\alpha$  in both groups (ASD:  $\alpha = 0.91$ ,  $n = 72$ ; TD:  $\alpha = 0.90$ ,  $N = 59$ ). Cronbach's  $\alpha$  was good for the total hyper-responsiveness scale (ASD:  $\alpha = 0.87$ ,  $n = 75$ ; TD:  $\alpha = 0.85$ ,  $n = 66$ ) and the total hypo-responsiveness scale (ASD:  $\alpha = 0.85$ ,  $n = 75$ ; TD:  $\alpha = 0.81$ ,  $n = 60$ ) in both groups as well. The internal consistencies of the GSQ modalities varied slightly from unacceptable to good (George and Mallery, 2003), for details see Table 3.

Of the 146 participants, 109 also filled in the GSQ for a second time. Overall, the median time between the first and the second time the GSQ was administered was 14.9 weeks (range: 10.6–68.0 weeks). One ASD participant had more than 10% missings on the GSQ the second time and was, therefore, removed from the test–retest reliability analysis. The test–retest reliability correlation was high for the ASD group ( $r=0.92$ ;  $p<0.001$ ;  $n_{ASD}=58$ ) as well as for the TD group ( $r=0.83$ ;  $p<0.001$ ;  $n_{TD}=50$ ).

**Table 3.** Cronbach’s  $\alpha$  GSQ subscales.

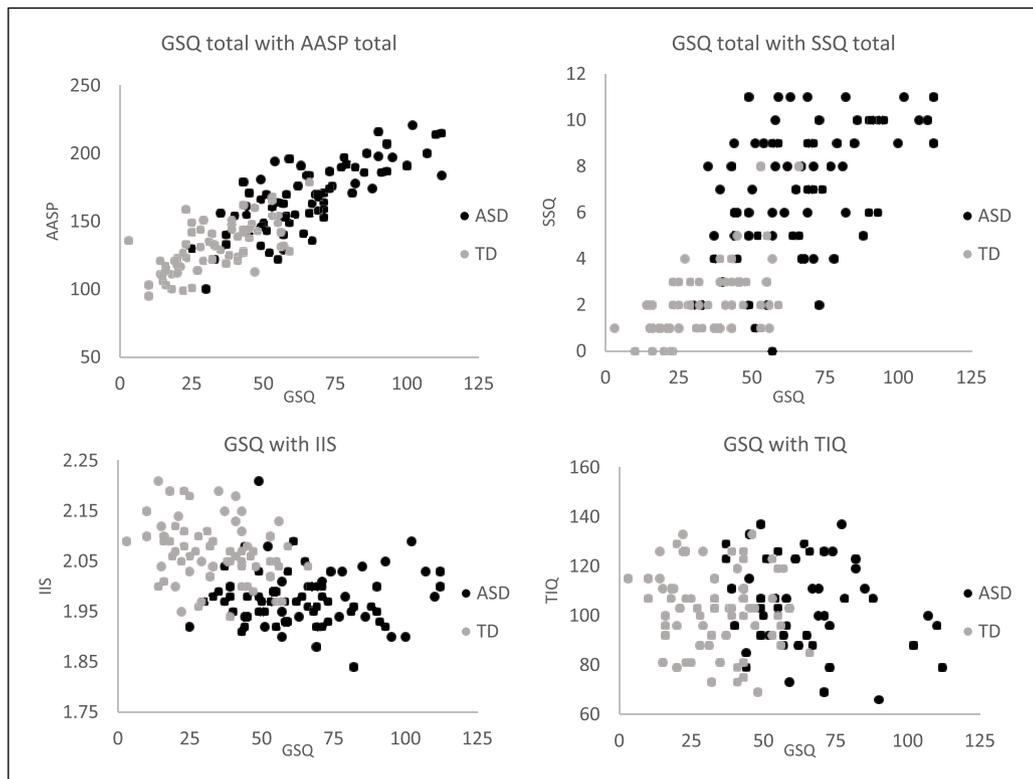
| GSQ subscales  | N             | ASD  | TD   |
|----------------|---------------|------|------|
| Visual         | 77 ASD; 66 TD | 0.75 | 0.67 |
| Auditory       | 78 ASD; 68 TD | 0.61 | 0.71 |
| Gustatory      | 78 ASD; 68 TD | 0.57 | 0.64 |
| Olfactory      | 77 ASD; 67 TD | 0.50 | 0.44 |
| Tactile        | 78 ASD; 67 TD | 0.42 | 0.44 |
| Vestibular     | 76 ASD; 67 TD | 0.73 | 0.50 |
| Proprioception | 76 ASD; 63 TD | 0.67 | 0.53 |

ASD: autism spectrum disorder group; N = number of participants; TD: typically developing group.  
 The numbers in the ASD and TD column are Cronbach’s alpha.  
 \*\*\* $p \leq 0.001$ .

**Convergent and divergent validity**

Between the total scores of the GSQ and AASP, there was a strong positive relationship in the ASD group ( $r=0.77$ ,  $p<0.001$ ; see also Figure 1) and a moderate to strong positive relationship in the TD group ( $r=0.66$ ,  $p<0.001$ ). In the ASD group, the GSQ total score had a moderate positive correlation with the AASP quadrant Low Registration ( $r=0.55$ ,  $p<0.001$ ), a strong positive correlation with Sensory Sensitivity ( $r=0.70$ ,  $p<0.001$ ), a moderate positive correlation with Sensation Avoiding ( $r=0.57$ ,  $p<0.001$ ), and a small non-significant correlation with the AASP quadrant Sensation Seeking ( $r=0.17$ ,  $p=0.20$ ). In the TD group, these correlations were moderate and positive for the AASP quadrant Low Registration ( $r=0.51$ ,  $p<0.001$ ), the Sensory Sensitivity ( $r=0.48$ ,  $p<0.001$ ), and the Sensation Avoiding ( $r=0.49$ ,  $p<0.001$ ). The AASP quadrant Sensation Seeking showed a small to moderate correlation with the GSQ total score ( $r=0.38$ ,  $p=0.007$ ). Moreover, there was a moderate positive correlation between the GSQ and SSQ total scores for both the ASD group ( $r=0.51$ ,  $p<0.001$ ) and TD group ( $r=0.56$ ,  $p<0.001$ ).

The GSQ total score had a small non-significant correlation with IIS in the ASD group ( $r=0.03$ ,  $p=0.78$ ) and a small negative correlation in the TD group ( $r=-0.25$ ,



**Figure 1.** Convergent and divergent validity. Top left: correlation between GSQ total score and AASP total score. Top right: correlation between GSQ total score and SSQ total score. Bottom left: correlation between GSQ total score and IIS total score. Bottom right: correlation between GSQ total score and TIQ.

**Table 4.** Correlations between hypo- and hyper-sensitivity subscales GSQ.

| GSQ subscales  | N             | ASD    | TD     | z score | p value |
|----------------|---------------|--------|--------|---------|---------|
| Total          | 78 ASD; 68 TD | 0.60** | 0.73** | -1.32   | 0.19    |
| Visual         | 77 ASD; 66 TD | 0.57** | 0.48   | 0.67    | 0.50    |
| Auditory       | 78 ASD; 68 TD | 0.15   | 0.35   | -1.23   | 0.22    |
| Gustatory      | 78 ASD; 68 TD | 0.24   | 0.41   | -1.13   | 0.26    |
| Olfactory      | 77 ASD; 67 TD | 0.27   | 0.19   | 0.49    | 0.62    |
| Tactile        | 78 ASD; 67 TD | 0.02   | 0.21   | -1.14   | 0.25    |
| Vestibular     | 76 ASD; 67 TD | 0.39** | 0.22   | 1.08    | 0.28    |
| Proprioception | 76 ASD; 63 TD | 0.57** | 0.37*  | 1.42    | 0.16    |

ASD: autism spectrum disorder group; TD: typically developing group; GSQ: Glasgow Sensory Questionnaire.

These are Pearson's correlations between the hypo- and hyper-sensitivity subscale scores per modality per group. Bonferroni correction:  $0.05/16=0.003$ . We used *r*-to-*z* transformations of Fisher (two-tailed) to compare the correlation coefficients between ASD and TD. A *z* score above 1.96 or below -1.96 is interpreted as a significant difference.

\*Significant correlation with  $p \leq 0.003$ ; \*\* $p \leq 0.001$ .

$p=0.04$ ). The correlation between the GSQ total score and TIQ was small, non-significant, and negative for both the ASD group ( $r=-0.23$ ,  $p=0.09$ ) and the TD group ( $r=-0.13$ ,  $p=0.28$ ). These correlations are significantly lower than the correlations between the GSQ total score and the total AASP score in the ASD group ( $r=0.03$  vs  $r=0.77$ ,  $z$  score=5.96,  $p < 0.001$ ; and  $r=-0.23$  vs  $r=0.77$ ,  $z$  score=6.92,  $p < 0.001$ ) as well as in the TD group ( $r=-0.25$  vs  $r=0.66$ ,  $z$  score=5.96,  $p < 0.001$ ; and  $r=-0.13$  vs  $r=0.66$ ,  $z$  score=5.26,  $p < 0.001$ ).

### Hypo- and hyper-sensitivity

In each group, the total hypo-sensitivity score had a moderate positive correlation with the total hyper-sensitivity score (see Table 4). In the ASD group, hypo- and hyper-sensitivity scores on the visual, vestibular, and proprioception subscale were moderately positive related to each other. In the TD group, this was only the case for the proprioception subscale. All these correlation coefficients did not significantly differ between the ASD and TD groups (see Table 4). The correlation matrix (see Figure 2) also showed no significant difference in correlations between the hypo- and hyper-sensitivity modalities (14 subscales in total) between the two groups ( $\chi^2=104.05$ ,  $p < 0.17$ ).

### Clinically relevant features

Overall, the RCI of the GSQ-NL was 17.5, which is the number of points of change on the GSQ-NL that is considered significant. In our sample, only two TD adults significantly changed for the better (i.e. 20 and 25 points less).

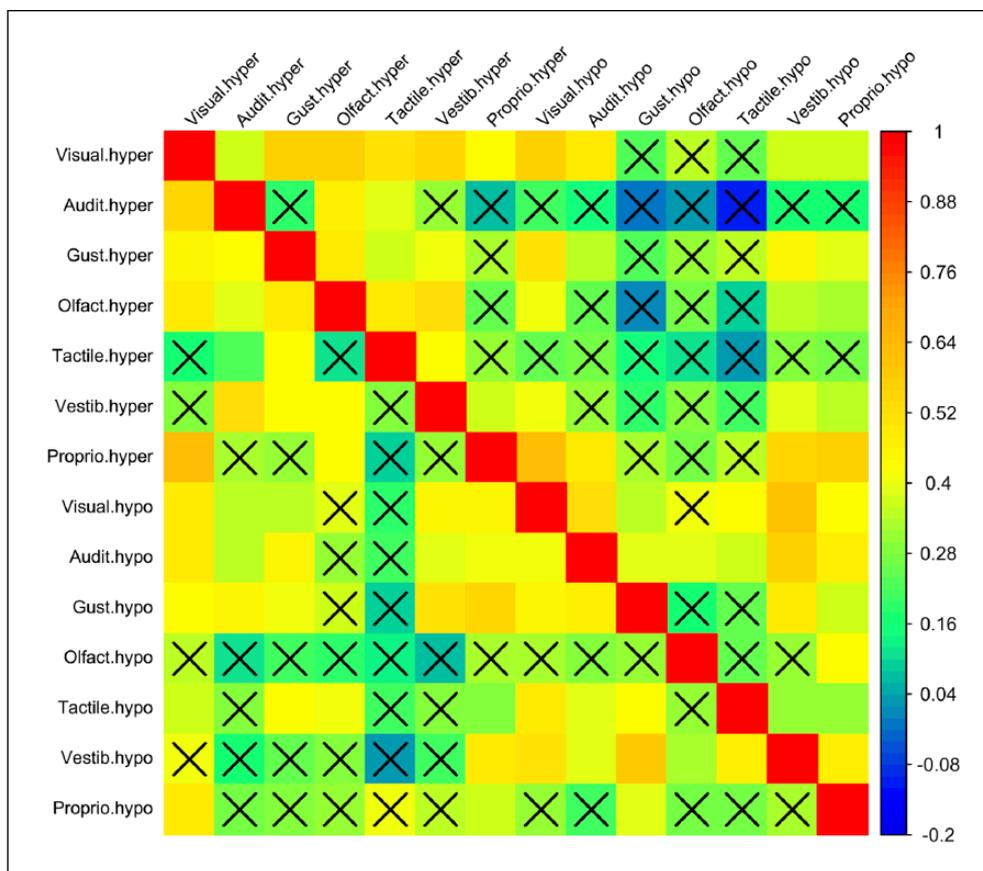
In the TD group, the 95th percentile started at 56.55, which, by definition, means that 5% of the TD adults ( $n=3$ ) had a score that was higher than or equal to 56.55 on the GSQ. In the ASD group, 64.1% scored above the 95th percentile of the TD group ( $n=50$ ). When using the 98th

percentile cut-off, still 50% ( $n=39$ ) of the ASD group had significantly high sensory sensitivity scores.

### Discussion

The aim of this study was to determine the psychometric properties of the Dutch version of the GSQ (GSQ-NL) and to assess its clinical value. In line with previous studies (Horder et al., 2014; Robertson and Simmons, 2013; Sapely-Triomphe et al., 2017; Takayama et al., 2014; see Table 4), we showed that the GSQ-NL had, overall, good psychometric properties. The validity was good as it had a strong positive relation with other self-report sensory sensitivity questionnaires (i.e. AASP and SSQ) and a much weaker negative relation with a social skills questionnaire (i.e. IIS) and no relation with a completely other construct (i.e. TIQ). The weak relationship between sensory sensitivity and social skills is in line with recent studies (e.g. Hilton et al., 2010; Ronconi et al., 2016; Thye et al., 2017). In both groups, the reliability of the GSQ-NL total score was excellent and good for the total hyper- and hypo-responsiveness scores (George and Mallery, 2003). The internal consistency of each individual modality was lower than the consistency of the total score, but this can be expected as the subscales have fewer items (e.g. Namdeo and Rout, 2017). The GSQ-NL total score showed a strong positive relationship with the total AQ score as well (see Table 5), indicating that people with more autistic traits report more sensory sensitivities. Specifically, our additional analysis showed that about two thirds of the autistic adults report to have extreme (either hypo- or hyper-) sensory sensitivities. In addition to the previous literature, we determined the test-retest reliability as well, which was excellent. Hence, from a psychometric perspective, the GSQ-NL seems a valuable addition to the autism assessment toolbox.

However, the question is whether the GSQ-NL also can be of clinical use. Given the current findings, we believe that this is the case for two reasons. First of all, the GSQ-NL



**Figure 2.** Correlation matrix (online in color). The colors represent the strength of the spearman correlations between the hypo- and hyper subscales of the GSQ of the ASD (upper half of the matrix) and TD group (lower half of the matrix). Bonferroni correction ( $0.05/14=0.004$ ) has been done to correct for the 14 correlations per group. Non-significant correlations ( $p > 0.004$ ) are marked with an X.

**Table 5.** Comparison GSQ-NL to GSQ original, Japanese, and French version.

|                           | Cronbach's $\alpha$ | Correlation with AQ (r) | Correlation with AASP (r) | Correlation with another construct (r) | Test-retest reliability (r) |
|---------------------------|---------------------|-------------------------|---------------------------|--|-----------------------------|
| GSQ-NL <sup>a</sup>       | 0.94                | 0.75                    | 0.84                      | -0.48                                  | 0.93                        |
| Original GSQ <sup>b</sup> | 0.94                | 0.78                    | 0.72                      | 0.42                                   | -                           |
| Japanese GSQ <sup>c</sup> | 0.93                | 0.55                    | -                         | -                                      | -                           |
| French GSQ <sup>d</sup>   | 0.95                | 0.84                    | -                         | -                                      | -                           |

GSQ: Glasgow Sensory Questionnaire; GSQ-NL: Dutch Glasgow Sensory Questionnaire; AASP: Adult/Adolescent Sensory Profile.

<sup>a</sup>GSQ-NL translated by us. Cronbach's  $\alpha$ , correlations with AQ (also used as inclusion criterion), AASP, other construct (social skills; IIS) and the test-retest reliability are based on a combined group of autistic and TD adults.

<sup>b</sup>Original GSQ by Robertson and Simmons (2012). Cronbach's  $\alpha$ , correlation with AQ, with AASP (from Horder et al., 2014), and with other construct (anxiety; STAI; Horder et al., 2014), all based on general population.

<sup>c</sup>Japanese GSQ translated by Takayama et al. (2014). Cronbach's  $\alpha$ , correlation with AQ, both based solely on autistic adults.

<sup>d</sup>French GSQ translated by Sapey-Triomphe et al. (2017). Cronbach's  $\alpha$ , correlation with AQ based on mixed population of autistic and TD adults.

provides the ability to distinguish between hypo- and hyper-sensitivities in autistic adults, which is relevant information for both diagnostic and intervention trajectories. For instance, clinicians are better able to adjust their interventions to their individual patient needs if necessary. Our analyses showed that both the hypo- and hyper-sensitivity subscales of the GSQ-NL were reliable. Moreover, both clinical reports and previous studies indicate that some

autistic people are hypo- and hyper-responsive within the same modality (e.g. Elwin et al., 2012), which is thought to be context dependent (Sapey-Triomphe et al., 2017). With the GSQ, one can determine both hypo- and hyper-responsive scores within the same modality. In our study, hypo- and hyper-sensitivity to visual, vestibular, or proprioceptive modality often co-existed in the ASD group. This is partially in line with the Sapey-Triomphe et al. (2017) findings

as they observed this relationship across a wider range of modalities in a high AQ group (i.e. auditory, gustatory, and tactile modality). In contrast, in the TD group, hypo- and hyper-sensitivity only co-existed in the proprioception modality and across modalities (i.e. the total hypo- and hyper-score). This is similar to Sapey-Triomphe et al. (2017), although in that study for the low AQ group such a relationship was also found in the auditory modality. In contrast with the Sapey-Triomphe study (2017), we did not observe a higher concordance of hypo- and hyper-sensitivity within the same sensory modality in autistic adults. The overall pattern of correlations between hypo- and hyper-sensitivity subscales was similar among those with and without ASD. A potential explanation for this discrepancy in findings is that the autistic participants in our study reported less sensory sensitivities than the high AQ group included in the Sapey-Triomphe study (64.95 vs 82.80, respectively), while our TD group reported similar sensory sensitivities compared to their low AQ group (33.53 vs 41.6, respectively). So, the difference in reported sensory sensitivity between the two groups seems smaller in our study, and combined with the inclusion of smaller sample sized as Sapey-Triomphe et al. (2017), this might have resulted in insufficient power to result in a similar pattern of findings when using a similar statistical approach. Therefore, while we do conclude that hypo- and hyper-sensitivity can co-exist within the same modality, replication is needed to determine whether there are (no) differences between autistic and TD adults in how often such a co-existence occurs.

The second reason why the GSQ-NL is of clinical use is that the GSQ-NL showed to be stable over a time period of about 3 months. Both clinicians and researchers alike can calculate the individual clinically significant change scores (see the RCI formula in the “Methods” section). This is important as one needs to be assured that the change in score is a clinically significant change (e.g. due to treatment) and not due to random variation. When we calculated the RCI for our sample (i.e. 17.5), only two TD adults showed a spontaneous significant improvement in their overall sensory sensitivity. However, none of the autistic adults showed a significant change in overall self-reported sensory sensitivity, even though four autistic adults started a treatment that was focused on sensory sensitivity during the test–retest interval. The fact that the GSQ-NL is very stable over time raises the question of not only whether changes in sensory sensitivity will be picked up by the GSQ-NL but also whether sensory sensitivity can actually be improved by, for instance, treatment. So far, there seems to be limited evidence for the effectiveness of sensory sensitivity treatments, but studies are often hampered by methodological limitations (for review, see Cascio et al., 2016). However, the general assumption is that sensory function can be influenced by environmental factors and that it is probably susceptible for treatment (Cascio et al., 2016).

Although we examined the psychometric properties of the GSQ thoroughly, including several previously unstudied important aspects, there are some considerations and limitations to our study. First, one needs to be aware that the GSQ does not measure sensory perception (e.g. thresholds) but it measures affective and behavioral responses to sensory stimuli. Second, Figure 2 shows that there are considerable differences in which modalities co-occur. Research into specific multisensory patterns or possible underlying biological substrates in autism is, as far as we know, scarce (for reviews, see Baum et al., 2015 or Schauder and Benneto, 2016). The term “multisensory” refers to the involvement of several senses simultaneously, such as a combination of the auditory and visual sense. Autobiographical accounts suggest that there are indeed various combinations of sensory sensitivities across modalities (e.g. Elwin et al., 2012). The next step to enhance our understanding of sensory (processing) difficulties in ASD is a multisensory approach (for review, see Baum et al., 2015). Our study certainly shows multiple self-reported sensory sensitivities that often seem to co-occur (e.g. visual hyper-responsiveness and gustatory hyper-responsiveness in the ASD group and visual hyper-responsiveness and proprioception hyper-responsiveness in the TD group), which perhaps could serve as a starting point for future multisensory studies. Third, there are suggestions that there might be sex differences in how we perceive sensory stimuli (e.g. Keogh and Birkby, 1999), but we did not design the study to allow examination of possible sex differences on GSQ-NL scores. However, Horder et al. (2014) did show that there was no sex difference in total GSQ score. Whether men and women report a similar amount of sensory sensitivity on each modality or whether there are sex differences regarding hypo- or hyper-responsiveness is an interesting future research avenue. Fourth, for clinical use it would be valuable to have norm scores, which is something we could not yet provide. Finally, we only included autistic adults without intellectual disabilities. Future research should provide insight into whether the GSQ(-NL) is suitable for autistic adults with intellectual disabilities as well, but for now we conclude that the GSQ is a valid and reliable sensory sensitivity questionnaire that can be used for research as well as for clinical purposes at least for those autistic adults who do not have intellectual disabilities.

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