Analysis of the Relationship Between Intelligence, Sensory Processing Sensitivity and the Digital Tree Drawing Test: A Feasibility Study

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Abstract: The personality trait of intelligence has a research history rich in psychometric tradition, whereas sensory processing sensitivity is a young construct, which in its conceptualization shows similarities with other psychological and psychopathological concepts such as introversion, autism spectrum disorder, but also various giftedness concepts. The digital tree drawing test recently achieved good results in the diagnostics of cognitive performance losses in adults. The present study investigates whether the characteristics of intelligence and sensitivity are related and can be mapped in a second step using the digital tree test in the drawing process. For this purpose, 19 children and adolescents with existing intelligence and sensitivity diagnoses underwent the digital tree test. The results were evaluated using correlation analyses. Hardly any significant correlations were found between intelligence and sensitivity. Contrary to the previous assumption, the correlations found were negative. Drawing parameters, on the other hand, showed clear correlations with both traits, but here primarily with the sensitivity facets, so that drawing process variables could be identified which appear to be relevant for the personality traits. Future research could investigate in greater depth the direction and predictive value of these correlations in order to expand the diagnostic repertoire of psychological practitioners using the digital tree drawing test.

1 INTRODUCTION

Sensitivity is generally understood as a sensitivity in one's own experience of feelings and in dealing with other people. Early descriptions of the characteristic go back to the psychoanalyst Carl Gustav Jung (1875-1961), who wrote about sensitivity and introversion in his typology of characters (Jung, 1913). The developmental psychologist Jerome Kagan and its team also contributed the first indications of the characteristics of high sensitivity: they found, for example, that a certain percentage of babies appear to be more open to stimuli than the rest (Kagan et al., 1994). After following his participants for many years, he found that these more open babies develop into more “inhibited” children and adolescents. They are more cautious, reserved and deliberate (Kagan et al., 1994), which is reminiscent of today's descriptions of highly sensitive people, or HSP for short (Aron & Aron, 1997).

It is only in recent years that this temperamental trait has become the focus of scientific research alongside social discourse, which is reflected in a rapid increase in publications. Leading researchers in the field of sensitivity predominantly use the term sensory processing sensitivity (SPS) in their studies, which highlights the connection between sensitivity and the underlying processing (Greven et al., 2019). This makes SPS, alongside differential susceptibility (Belsky & Pluess, 2009) and biological context sensitivity (Ellis & Boyce, 2011), one of the theories of environmental sensitivity, an umbrella term for the perception and processing of environmental stimuli and the individual characteristics of these abilities (Pluess, 2015). According to Jagiellowicz et al. (2016), highly sensitive people are characterized by deeper stimulus processing and attention to detail, a tendency to overstimulation and emotional reactivity.

Twin studies have shown a genetic variance explanation of 47%, which means that almost half of

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the inter-individual sensitivity differences can be explained genetically and the other half by common and different environmental influences and the measurement error, answering the question of etiology (Assary et al., 2021).

A study examining brain activity found that people with a high SPS had slower reaction times (Jagiellowicz et al., 2011). Brain regions associated with visual processing and attention were significantly more activated in these individuals, so that more subtle stimuli and changes could be perceived.

Another fMRI study found connections between SPS and attention, empathy, action planning and situational awareness through altered activity in the insula, which is responsible for the integration of sensory stimuli and consciousness, and the medial temporal gyrus, which is associated with the recognition of faces (Acevedo et al., 2014).
A connection was also found with the premotor cortex, where the mirror neurons are located, which are responsible for recognizing the emotions of other people, thus enabling empathy (Greven et al., 2019).

A recent study also showed that SPS is associated with increased resting-state connectivity (Acevedo et al., 2021). Another finding by Aron et al. (2010) was, that SPS acts as a moderator for cultural differences in the processing of visual-spatial tasks and that people with high SPS therefore show fewer problems in solving non-culturally congruent tasks.

While SPS was initially conceptualized as a unidimensional construct, we now know about its three-dimensional structure: Aesthetic Sensitivity, AES for short, describes openness and appreciation for aesthetic and positive stimuli. The Low Sensory Threshold, LST for short, stands for the perception of subliminal and detailed stimuli and the associated attention to things that other people do not notice. Ease of Excitation, or EOE for short, refers to rapid overstimulation by extra- and intrapersonal stimuli and thus relates to the intensity of perception (Pluess et al., 2018; Smolewska et al., 2006).

Although sensitivity is a continuous trait, people can be divided into sensitivity groups, where the less sensitive make up about 20-25%, the moderately sensitive about 41-47% and the highly sensitive about 20-35% (Lionetti et al., 2018). As a disjunctive personality trait, high sensitivity is not pathological; neither high nor low sensitivity are problematic on their own. However, in combination with negative events and environments, the risk of mental illness like depression or anxiety and unfavorable developmental trajectories increases, which underlines the importance of correctly identifying highly sensitive individuals and conducting in-depth research into the personality trait (Greven et al., 2019; Krampe & van Randenborgh, 2023).

Intelligence is often conceptualized as a more cognitive trait, with aspects such as short- and long-term memory or fluid and crystallized intelligence as in the Cattell-Horn-Carroll theory or CHC theory for short (Schneider & McGrew, 2012). However, there are also more comprehensive concepts that describe intelligence more broadly and include factors such as social behavior (Heller, 2013) or creativity (Renzulli, 2011). Therefore, intelligence is considered a personality trait and, according to Wechsler's (1940) definition, it describes a general competence to deal constructively with one's environment. Due to aspects of SPS that overlap with the different facets of intelligence, a possible link between both traits is obvious. However, the number of studies on a possible connection between SPS, i.e. high sensitivity, and giftedness has been sparse to date, although there are also studies on related sensitivity terms that overlap with SPS in their definition (Gallagher, 2022; Samsen-Bronsveld et al., 2024; Winkler & Voight, 2016).

The tree drawing test was originally developed as a projective method for determining past traumas by unraveling the unconsious aspects of the psyche, but it is also established in giving insights on one's developmental stage by displaying cognitive and emotional competences (Koch, 2008). Although it is primarily applied by interpreting the drawing as a whole, the digitized version focuses on the drawing process rather than the finished image and has proven itself in the field of Alzheimer's and dementia diagnostics as well as the determination of cognitive impairments (Faundez-Zanuy et al., 2014; Robens, Heymann, et al., 2019).

In the present study the digital tree drawing test is used for assessing the cognitive strengths of young people. The basic idea is that the mechanisms of the drawing process, which indicate cognitive impairments, have elementary connections to cognitive and perceptual abilities, which could therefore also be evident on the other side of the spectrum, i.e. higher sensitivity.

Based on these considerations, we hypothesize that intelligence and sensitivity can be mapped individually via the drawing process in the digital tree drawing test. The digital tree drawing test therefore represents a non-verbal test procedure for determining intelligence and sensitivity that complements psychometric procedures.

2 MATERIAL AND METHODS

2.1 Recruitment and Setting

Participants were recruited from the ENergietankstelle Hattingen or the Institut AMBITION. Both are psychotherapeutic care facilities for children, adolescents and adults and a psychological testing center that focuses on people with high sensitivity and people with giftedness.

The prerequisites for participation in the study were the existence of an intelligence assessment and a completed sensitivity assessment. The test batteries used to determine intelligence were almost all from the Wechsler test family.

The study took place on the premises of the practices. These are familiar to the participants and act as a safe place for them, where they can feel comfortable. The test administrator and the test subject were present during the test.

2.2 Assessment Methods

The tree drawings were made on a Microsoft Surface Pro 3 tablet. The tablet has a 64-bit Windows 8.1 Pro operating system, a 1.7 GHz Intel Core i7-4650U dual-core processor with a maximum CPU frequency of 3.3 GHz, 8 GB of RAM and a resolution of 2160 x 1440 pixels. To draw on the tablet, a pressure-sensitive digital pen with 4096 pressure sensitivity levels was used (Figure 1).

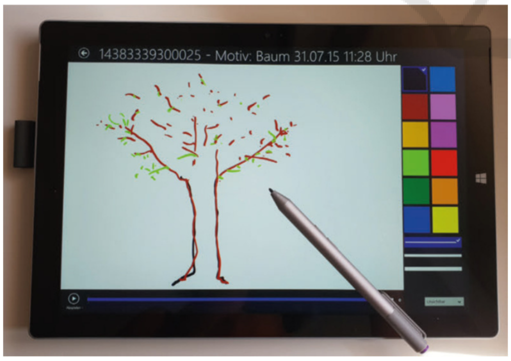

Figure 1: Microsoft Surface for the digital Tree Drawing Task taken from (Robens & Ostermann, 2020).

After familiarizing themselves with the tablet participants were asked to draw a tree of their choice. In total, no test took more than 30 minutes.

The intelligence and sensitivity values of the participants had already been collected in advance, independently of the present study, using the Wechsler Intelligence Scale for Children - Fifth Edition (WISC-V) by Petermann (2017) or previous versions and the short version of the Highly Sensitive Child Scale (HSC) by Pluess et al. (2018). Although sensitivity is a normally distributed and continuous characteristic, it can be divided into three sensitivity groups: HSC-values lower than 3.8 indicate lower sensitivity, values between 3.8 and 4.7 point towards a moderate sensitivity and values higher than 4.7 indicate high sensitivity.

2.3 Digital Tree Drawing Variables

From the digital tree drawing process, the following 16 variables were extracted:

- Total time (s)
- Drawing time (s)
- Not drawing (%)
- Pen pressure
- Pressure-velocity relation
- Color changes
- Color count
- Strokes per minute
- Line width changes
- Line widths
- PenUp count
- PenUp (%)
- PenUp drawing relation
- PenUp line length
- Mean velocity
- Volatile motion

2.4 Statistical Procedures

Data was first summarized using descriptive statistics. For this purpose, mean values and standard deviations, minimum, maximum and medians were calculated for metrical variables and percentages for nominal variables. All analyses were subdivided into highly sensitive and low-moderate sensitive individuals.

To test the hypothesis mentioned at the end of Chapter 1, Pearson's correlation coefficient were calculated to determine whether sensitivity values were associated with drawing characteristics. For this purpose, the sample was considered as a whole and not subdivided into groups. All analyses were carried out using SPSS for Windows Version 28.

3 RESULTS

3.1 Sample

The study sample comprises 19 children and adolescents (11 females and 8 males) aged between 7 and 18 (mean age: 12.5 ± 2.2 years) with a mean IQ of 124.05 ± 9.41. The sample includes three less sensitive people (all males) with HSC values < 3.8, eight moderately sensitive people (all females) with values between 3.8 and 4.7 and eight highly sensitive people (3 females and 5 males) with sensitivity values > 4.7. Table 1 compares the highly sensitive people with the low and moderately sensitive people and lists further sociopsychological data on the participants.

Table 1: Sociopsychological data of the total sample (Abbrev: SPS: Sensory Processing Sensitivity; EOE: Ease of Excitation; LST: Low Sensory Threshold; AES: Aesthetic Sensitivity).

	High SPS	Low/Mod. SPS	Total
Gender			
Male	5 (62.5 %)	3 (27.3 %)	8 (42.1 %)
Female	3 (37.5 %)	8 (72.7 %)	11 (57.9 %)
Age (yrs)			
M ± SD	12.3 ± 1.6	12.6 ± 2.7	12.5 ± 2.2
Median	12.5	12	12
IQ			
M ± SD	124.1 ± 8.2	124.0 ± 10.6	124.1 ± 9.4
Median	125	125	125
SPS-Total			
M ± SD	5.7 ± 0.58	3.98 ± 0.46	4.70 ± 1.01
Median	5.5	4.08	4.5
SPS-EOE			
M ± SD	5.7 ± 0.65	3.91 ± 0.94	4.66 ± 1.22
Median	5.6	4	5
SPS-LST			
M ± SD	5.65 ± 0.77	2.61 ± 0.88	3.89 ± 1.74
Median	5.46	2.83	3.33
SPS-AES			
M ± SD	5.71 ± 0.64	5.15 ± 0.7	5.39 ± 0.72
Median	5.62	5.5	5.5

3.2 Key Results

Table 2 shows the features extracted from the digital tree drawing test. Once again, the highly sensitive people are compared with the low and moderately sensitive people. As can be clearly seen, there are significant differences between the two groups in terms of digital tree drawing values. This becomes also evident in the correlation analysis, of which the Pearson correlation values are shown in Table 3.

As can be seen in Table 3, the total HSC score (SPS) correlated significantly positively with the pressure-velocity relation (r = .461, p < 0.05), the line width changes (r = .461, p < 0.05) and the PenUp percentage (r = 489, p < 0.05) and highly significantly negatively with the jumpy character movements (r = -.634, p < 0.01).

Table 2: Features extracted from the digital tree drawing test. Data is given in Mean ± SD.

	High SPS	Low/Mod. SPS	Total
Total time (s)	649.58 ± 238.70	500.88 ± 294.01	563.50 ± 275.45
Drawing time (s)	265.21 ± 144.49	250.83 ± 107.22	256.89 ± 120.66
Not drawing (%)	0.58 ± 0.18	0.42 ± 0.18	0.49 ± 0.19
Pen pressure	0.25 ± 0.09	0.25 ± 0.09	0.25 ± 0.09
Pressure-velocity relation	2.08 ± 1.01	1.35 ± 0.68	1.66 ± 0.88
Color changes	18.88 ± 7.51	15.18 ± 17.94	16.74 ± 14.294
Color count	5.5 ± 1.85	5.36 ± 2.91	5.42 ± 2.45
Strokes per minute	46.31 ± 23.65	31.34 ± 36.93	37.65 ± 32.14
Line width changes	9.13 ± 10.629	6.82 ± 4.35	7.79 ± 7.47
Line widths	2.75 ± 0.46	2.55 ± 0.68	2.63 ± 0.59
PenUp count	476.88 ± 249.01	328.55 ± 544.65	391.00 ± 441.11
PenUp (%)	0.30 ± 0.10	0.21 ± 0.13	0.25 ± 0.12
PenUp-drawing relation	0.99 ± 0.75	0.49 ± 0.50	0.70 ± 0.65
PenUp line length	26702.86 ± 16833.60	20906.44 ± 39381.20	23347.03 ± 31312.04
Mean velocity	8.25 ± 5.18	10.53 ± 5.73	9.57 ± 5.48
Volatile motion	69.18 ± 29.88	103.07 ± 49.98	88.80 ± 45.06

The EOE facet shows a positive correlation with the pressure-velocity relationship (r = .532, p < 0.05), a negative correlation with the average velocity (r = -.556, p < 0.05) and a highly significant negative correlation with the abrupt drawing movement (r = -.663, p < 0.01).

The LST shows positive correlations with the Not Drawing percentage (r = .533, p < 0.05), with the PenUp percentage (r = .535, p < 0.05) and with the PenUp-drawing relation (r = .526, p < 0.05), as well as a negative correlation with the volatile motion (r = -.544, p < 0.05).

Although, some variables of the digital tree drawing test correlated with at least one of the HCS scales, the AES sensitivity facet was the only one that showed no significant correlations.

Table 3: Correlations between the digital tree drawing test and the HCS-Scales (**: The correlation is significant at the 0.01 level; *: The correlation is significant at the 0.05 level).

	SPS	EOE	LST	AES
Total time (s)	.304	.128	.361	.301
Drawing time (s)	.026	-.038	-.013	.170
Not drawing (%)	.431	.315	.533*	.169
Pen pressure	-.155	-.038	-.222	-.224
Pressure-velocity Relation	.461*	.532*	.415	.069
Color changes	.099	-.049	.125	.242
Color count	-.043	-.024	-.061	-.045
Strokes per minute	.245	.304	.282	-.096
Line width changes	.461*	.387	.387	.406
Line widths	.258	.339	.215	-.003
PenUp count	.194	.170	.262	-.003
PenUp (%)	.489*	.419	.535*	.229
PenUp-drawing relation	.421	.313	.526*	.146
PenUp line length	.094	.064	.186	-.095
Mean velocity	-.442	-.556*	-.292	-.187
Volatile motion	-.634**	-.663**	-.544**	-.308

4 DISCUSSION

4.1 Key Findings

The correlation analyses of the sensitivity and drawing values presented in this pilot study revealed a large number of significant or highly significant correlations.

Firstly, the overall sensitivity was positively related to the pressure/speed ratio, the number of stroke width changes and the percentage of time the digital pen is held in the air instead of being used for drawing. There is a significant negative association with erratic drawing movements. This coherently underpins the picture of sensitivity, according to which more sensitive people also pay attention to small differences and tend to proceed deliberately and carefully instead of acting impulsively or spontaneously (Aron, 1996; Aron et al., 2012).

Secondly, the EOE subscale also correlated positively with the pressure-speed relationship, was strongly negatively related to the average drawing velocity and the abrupt drawing movements and thus supports the impression that people with higher sensitivity appear to draw more cautiously, more nuanced and more slowly or, conversely, appear to be more sensitive with a more cautious drawing style.

And thirdly, the LST sensitivity factor is positively associated with the percentage of time not drawing and the time the pen is held over the tablet and negatively associated with erratic drawing movements. This again suggests that increased sensitivity, in this case in the area of a low sensory threshold, is associated with a more careful drawing style.

Future studies with higher sample size of that people with higher sensitivity could also include analyses to differentiate between different levels of sensitivity which have only been rudimentarily carried out here (Robens, Ostermann, et al. 2019; Unger, Bayram, et al. 2024). This could open up new and exciting fields of research, particularly in this area.

4.2 Limitations

From a methodological perspective, limitations of the present study can be identified. For example, there is a clear limitation in the sample size. Although a test subject group of 19 participants can indicate an initial direction and appears adequate for a small research project, a bigger sample size should be examined in order to achieve truly robust results.

Since most of the participants are clients of a psychotherapeutic practice with a focus on working with gifted children and adolescents, almost all of them have an above-average intelligence quotient. This means that the group is very homogeneous in terms of the characteristic of intellectual giftedness and correlations with other variables such as sensitivity or the sign parameters are difficult to identify.

With respect to the correlation analyses, it is important to note, that the results can be interpreted in both directions, as correlation analyses only show whether an association exist but not from which of the variables it originates. When analyzing the drawing variables with the personality traits, it nevertheless is more likely that personality traits influence the drawing process and not vice versa. However, this has to be taken into account in future research.

5 CONCLUSION

Various research findings in recent years show, on the one hand, that the personality trait of intelligence is constantly being evaluated and adapted to current scientific findings (McGrew, 2009) and, on the other hand, that alternative, not purely cognitive conceptualizations of intelligence and giftedness are increasingly gaining acceptance in society and in science (Renzulli, 2011, 2012). In its conception, sensory processing sensitivity includes, among other things, an increased perception of detail, attention to subliminal stimuli and a pronounced responsiveness to aesthetics (Pluess et al., 2018).

Due to partially overlapping and matching conceptualizations of both characteristics, there is reason to assume a positive correlation between the two characteristics, according to which one could act as a predictor for the other (De Gucht et al., 2023). This study investigated this possible correlation. Unfortunately, a reliable correlation between these characteristics could not be confirmed, as the group was too homogeneous in terms of intelligence. In a second step, it was examined whether these characteristics can be mapped independently of each other using the digital tree test and expressed in character variables. This worked well for cognitive impairment and psychiatric disorders in older people in other studies (Robens, Heymann, et al., 2019).

Despite these limitations, the participants in this study reported good experiences with drawing on the tablet, which speaks for the practicability and user-friendly implementation of the digital tree drawing test. In addition, the added value of this research project lies in the approach to a thematically still quite unexplored area. As the scoping review on digital drawings tools (Unger, Robens, et al., 2024) points out, there is no previous work that has investigated both personality traits, i.e. aptitude and sensitivity, in relation to the digital tree drawing test. It has even been found that children and adolescents are generally neglected in the assessment of mental conditions and efforts in this direction, for example, cover only the examination of the intuitive operation of a stylus (Wu et al., 2018). To all appearances, the digital tree drawing test has so far been used primarily in the area of cognitive disorders and psychiatric illnesses, but not in younger groups of people with more pronounced abilities. Sensory processing sensitivity, on the other hand, is still a young construct with a great need for research in order to minimize the risk of developing mental illnesses by finding adequate medical and societal understanding and handling. The present study therefore represents a first attempt to examine these different characteristics and processes in conjunction with each other in a young group of participants. This is important because different diagnostic tools are necessary for a multi-layered and individually accurate diagnosis and working with children and adolescents, who usually have less developed linguistic and reflexive skills than adults, poses particular challenges in this respect.

If it turns out that the tree test is a good tool, not only in terms of its projective qualities but also as a process-oriented means of testing high sensitivity, this would represent a significant gain for practicing diagnosticians.

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