Odor detection sensitivity and response bias in relation to aspects of health

Jocelyne Yacoub
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Chemical intolerance (CI) means that the affected individual experience symptoms from the smell of the weak concentrations of conventional chemicals in the environment that most people are not bothered by. This study aimed to examine whether response bias (beta) and sensitivity index (d') for odor detection correlate with self-rated health, CI, stress and distress. The questionnaires that were used to answer the question were self-rated health (SRH), CI (assessed with the Chemical Sensitivity Scale), stress (Perceived Stress Scale) and distress (Symptom Check List-90). A group of 23 adult individuals between the ages of 18 to 55 years expected to vary in degree of CI were exposed to various concentration of n-butanol for a signal detection test for about 2 hours. The data processing was done by correlational analyses. The results showed no statistically significant correlations between beta and the variables SRH, CI, stress and distress, but tendencies of significant correlations between d' and the variables SRH, CI and stress, such that individuals who were high in CI, stress and who generally felt poorly had a lower odor sensitivity (d'). These tendencies encourage continued study of the associations with larger sample size.

Kemisk intolerans (KI) innebär att den drabbade individen upplever symtom från lukten av svaga koncentrationer av konventionella kemikalier i miljön som de flesta människor inte besväras av. Denna studie syftade till att undersöka om respons-bias (beta) och känslighetsindex (d’) för luktdekction korrelerar med självskattad hälsa, KI, stress och allmän hälsa. De frågeformulär som användes för att svara på frågan var självskattad hälsa (SRH), KI (bedömd med Chemical Sensitivity Scale), stress (Perceived Stress Scale) och allmän mental hälsa (Symptom Check List-90). En grupp av 23 vuxna individer i åldrarna 18 till 55 år som förväntades variera i grad av KI exponerades för olika koncentrationer av n-butanol för ett signaldetektionstest under 2 timmar. Dataprocessen gjordes med korrelationsanalyser. Resultatet visade ingen statistisk signifikant korrelation mellan beta och variablerna SRH, KI, stress och allmän hälsa, men tendenser av signifikt korrelationer mellan d’ och variablerna SRH, KI och stress, på så sätt att individer som var höga i KI, stress och som allmänt kände sig mentalt dåliga hade en lägre luktkänslighet (d’). Dessa tendenser uppmuntrar till fortsatta studier av association med större stickprovstorlek.
Chemical intolerance (CI), or sensitivity to odors, means that the affected individual experience symptoms (e.g. nausea, headache, breathing difficulties) from the smell of the weak concentrations of conventional chemicals in the environment that most people are not bothered by (S. Nordin, Millqvist, Löwhagen, & Bende, 2003). Furthermore, chemical intolerance is similar in many ways to asthma and allergy, with symptoms from the respiratory, skin and mucous membrane and indigestion. Examples of substances that cause symptoms are perfumed products, fabric softeners, and strongly scented flowers (Dantoft, Andersson, Nordin, & Skovbjerg, 2015). A person who gets headaches and nausea from passing by perfume scent can be declared to have CI. This also applies to a person who avoids smoker by passing over to the other side of the street, and also for someone who feels smothered by aftershave that a colleague uses (Andersson, 2012). CI includes diagnoses of multiple chemical sensitivity (MCS) that contains several different criteria and sensory hyperreactivity (SHR), which is a special form of CI that is mainly linked to respiratory problems. CI affects both young adults and older people in the Western and other parts of the world such as Cambodia and Vietnam, a major risk group is women (Andersson, 2012). Further, it is documented that chemical intolerant people who have more severe symptoms than others have a limited quality of life. The affected person avoids certain places that make them sick. For this group it can also lead to social isolation, financial problems and difficulties in finding housing (Söderholm, Söderberg, & Nordin, 2011). It is common that the victims are not taken seriously by health care and have difficulty obtaining financial support in the form of sickness allowance (Skovbjerg, Johansen, Rasmussen, Thorsen, & Elberling, 2009).

As the sense of smell is so important in CI it is essential to firstly discuss smell function in humans. The sense of smell plays an important part in our daily lives, and is consequently a complex mental phenomenon and is influenced by other senses and non-sensory input (Sell, 2014). An important function of human olfaction is to guide the individual’s attention towards dangers (e.g., spoiled food and poisonous fumes). Also towards items that in a general sense have positive connotations (e.g. nutritious food). A necessity of an odorous substance to warn or attract individuals is that at an earlier encounter with the substance is associated with a positive or negative emotion depending on the context. Additionally, that we at a later occasion recognize the odor and retrieve the association from memory. Behavioral responses are thought to increase the relatively strong emotions that are often evoked by odors. Once encoded in memory, the forgetting curve for odor recognition is over time rather flat. Amygdala is an area of general importance for memory encoding and emotional experience and expression as well as for primary processing of olfactory information. The primary olfactory cortex has strong neural links to hippocampal formation of particular importance for recognition (Nordin, 2009).

A recent study exposed participants who were chemically intolerant and who meet the criteria for MCS. Participants sat inside an exposure chamber where they repeatedly estimated how strongly they perceived the odor, how unpleasant it was, and symptom intensity. Measurements of breathing, heart rate and sweating of the skin were also conducted. It was found that participants with CI estimated odors as stronger, and more unpleasant, experienced
symptoms as stronger, and had abnormal pulse compared to participants without CI. (Andersson et al., 2015).

Some studies suggest that CI is not characterized by higher ratings of perceptual properties, such as the intensity of an exposure. However, there are individuals with CI who rate olfactory chemical exposure as more intense, unpleasant and symptom eliciting, compared with controls. Other pathophysiological theories include the immune system, CNS, and olfactory and respiratory systems. In addition, CI may be associated with altered metabolic capacity, behavioral conditioning and psychiatric disorders (Dantoft et al., 2015).

Most modern detection threshold tests are based on the task to detect a stimulus on a given trial. In cases when the likelihood of false alarms is high, such as in olfaction, the test subject is asked which of two or several stimuli (e.g. an odorant and one or several blanks) is perceived as strongest, instead of simply reporting whether an stimulus is perceived or not (Doty, 1994). Signal detection theory (SDT) is a theory developed within psychophysics and decision theory (Swets, 2014). SDT is widely used and accepted by psychologists (Stanislaw & Todorov, 1999) and is based on the concept of two distributions of strength indication (usually normally distributed), one referred to as noise and another to signal + noise. In SDT the sensitivity can be obtained with statistics such as the sensitivity index or d prime (d’), and response bias can be estimated with statistics such as C and beta. High d’ indicates that the signal can be readily detected (Stanislaw & Todorov, 1999). d’ measures the distance between the signal and the noise means in standard deviation units. The measure d’ (a measure of sensitivity) is widely used and the reason is because its value does not depend upon the criterion the subject is adopting, but instead it is a true measure of the internal response (Stanislaw & Todorov, 1999). In SDT, four possible outcomes can be obtained, which are hits, false alarms, correct negative and misses. A hit means that the observer replies that a signal exists when there is a signal, and a miss means that the signal is given without the observer responding that the signal is given. False alarm means that the observer falsely answers that the signal exists, and correct negative that the observer correctly answers that no signal is given (Gescheider, 1997).

An extensively used measure of general health is self-rated health, which is based on a simple question that asks the participants to rate their current overall health on a 5-point scale, ranging from “excellent” to “poor”. Answers on the self-rated health scale have consistently been shown to be great predictors of survival, functional decline, future morbidity, and subsequent health service utilization (Goldman, Glei, & Chang, 2004). The self-rated health scale has been reported to be a predictor of mortality after adjusting for traditional risk factors, socio-demographics and measures of health status (Singh-Manoux et al., 2006). Studies in primary care found that self-rated health is associated with depression. Furthermore, it has been suggested that self-rated health may be an important predictor of poor depression outcome over time (Ambresin, Chondros, Dowrick, Herrman, & Gunn, 2014).

The participants in this present study took part in a signal detection test, which meant that their task was to detect a signal which in this case was a smell. Despite several attempts
(Dantoft et al., 2015), the scientific field has not been able to find an association between odor detection sensitivity and CI. To my knowledge there is a lack of studies regarding associations between response bias and CI as well as between detection sensitivity and response bias, on the one hand, and stress, distress and self-rated health, on the other hand. My question formulation is whether response bias (beta) and sensitivity (d’) correlate with self-rated health, CI, stress and distress.

It is of relevance to know whether people who are more intolerant to odors will apply a less strict criterion than those who are less intolerant. Could it be that they apply a less strict criterion and tend to perceive the environment in terms of more hazards, not only in the case of smell, and not only in the case of their own symptoms but when they interpret their environment?

**Method**

**Participants**
In this study 23 participants participated, 16 men and 7 women. The participant’s age was between 18-55 years with an average age of 27.9 (SD 8.35) years. Participants were recruited by convenience sampling by the author as well as through advertising in public places (such as on campus and on facebook). Exclusion criteria for participants were below 18 years of age and anosmia (total loss of smell sensitivity), pregnancy and smoking because (the latter conditions do also affect the sense of smell).

**Ethical considerations**
This research project was approved by the regional ethical review board in Umeå (Dnr 2015/99-31Ö). All participants received written and spoken information about the study. The information contained the purpose of the study and what the participation included (task and time etc.). Participation was voluntary and the test subjects could at any time discontinue their participation without having to provide any explanation. A signed informed consent was obtained from each participant. All data has been handled in a respectful and confidential manner. The participants’ confidentiality was guaranteed by decoding of the material. Participants were given 500 SEK as compensation for the time spent. In addition, the participants had the right to take part of their test results after preformed task.

**Procedure and materials**
This study is part of a larger research project and therefore all data that have been collected over time are not part of all my study. This project is part of the research program “Our unique sense of smell” (PIs: Maria Larsson and Linus Andersson). Participants visited the Department of Psychology, Umeå University on two occasions during a three-day period. All participants were tested individually in a single session that lasted between one and a half and two hours. The experiment took place in a laboratory; it was a quiet and private place at the University. During the first meeting, the participants put on a bracelet to measure autonomous activity (galvanic skin response and heart rate variability). Participants also got a log book to
take home, in which they noted strenuous or stressful situations. Furthermore, the participants did two cognitive tests which were Stroop and n-back (data from these parts of the first meeting were not part of this sub-study). At the end of the session the participants performed a signal detection test, in which they were presented weak odors (see Appendix A). Before initiating the odor test, the participants got to experience the odor stimulus with the strongest concentration to get to know the smell that they were to identify. They also got to experience the blank stimulus that only contained water. Participants were presented with a series of glass bottles either containing an odorant (n-butanol dissolved in water) or blank (water). Altogether there were ten glass bottles, of which seven contained a mixture of n-butanol and water, and three blank bottles contained only water. Dilution step twelve was the weakest concentration, six was the strongest concentration and B was blank (only water; Appendix A). The blank stimuli were presented 15 times and the other concentrations (6, 7, 8, 9, 10, 11 and 12) were presented 12 times. The total number of presented bottles was 126. Participants were also informed that the odor concentration would vary in strength. After 14 presentations there was a break for two minutes. Besides, the blank bottles that contained water were alternated so that they were not heated (giving possibly cues) by being placed in the hand more often than other bottles. The participant’s task was to determine if the bottle contained an odorant (n-butanol) or just water (blank). Before the bottle was given to the participants the experimenter shook the bottle and the participants smelled it for a few seconds and made an assessment. If the participant perceived a smell (n-butanol) he/she said “yes” and if not (just water) he/she said “no”. Before and after the signal detection test participants had to fill a questionnaire (ten different symptoms) to estimate their mood (not part of this sub-study). During the second meeting, participants filled out questionnaires (separated by a day).

Questions and questionnaire instruments

The Chemical Sensitivity Scale (CSS) was used to measure affective reactions and behavioral disruptions by odorous and/or pungent chemical substances, thus a quantification of CI. The CSS contains of 21 items (e.g. “At movies, other peoples’ perfumes and after shaves disturb me”), which the respondent evaluate the degree of agreement or disagreement on a six point Likert scale (0 = agree strongly, 5 = disagree strongly). (Cornell Karnekull, Jonsson, Larsson, & Olofsson, 2011; Nordin, Palmquist, Bende, & Millqvist, 2013). The score of the scale range from 1 to 105, and high score indicate high sensitivity (S. Nordin, Neely, Olsson, & Sandström, 2014). CSS is easy to use and has good reliability and validity. Cronbach’s alpha value for the CSS has been found to be .88, which indicates good internal consistency (S. Nordin et al., 2003).

The Perceived Stress Scale (PSS) was developed in 1983 by Cohen, Kamarck and Mermelstein (Cohen, 1983). PSS is widely used all over the world and translated to several languages (M. Nordin & Nordin, 2013). The version used in this study was PSS-10. PSS measures the degree to which individuals perceive certain stressful situations (Cohen, 1983). The PSS-10 consists of 10 items, and respondents are to rate each statement according to a five point Likert scale (0= never, 5= very often). For example respondents are asked: “In the last month, how often have you…” and includes items such as “felt nervous and stressed?” been upset about something that happened unexpectedly?”. Scores can range from 0-40 in
which high points represent high stress level. The Swedish version has showed to have good validity and reliability with an alpha value of .84 (M. Nordin & Nordin, 2013).

Symptom Checklist-90 (SCL-90) was developed during the 1970s by Derogatis and has been translated into many different languages. SCL-90 is a generally used self-report symptom inventory which measures the mental state of health during the past week. The form consists of 90 items that are divided into nine diagnostic subscales. The nine symptoms variables are: somatization, obsessive-compulsive, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoid ideation, and psychotism. The items are estimated on a five-point Likert scale ranging from 0 (“not at all”) to 4 (“very much”). The mean value of all 90 items constitutes the Global Severity Index (GSI), which is used in this study and highlights the general level of psychological disorders. The Swedish version of the SCL-90 has demonstrated high reliability; Cronbach’s alfa = .97 to .98 (Fridell, Cesarec, Johansson, & Thorsen, n.d.).

Self-rated health (SRH) was used to assess the general health status. Participants rated their health by answering one question which was “In general, how would you describe your health”? The item was on a five-point Likert scale (excellent, very good, good, fair or poor) (Ambresin et al., 2014; Goldman et al., 2004).

Statistical analysis

Statistical analyses were performed with IBM SPSS Statistics version 22.0. I have calculated Spearman’s correlation coefficients for the associations that include age, beta, d’, CSS, PSS-10 and SCL-90, with the exception of Person’s correlation coefficient for SHR. I also calculated the mean, standard deviation and minimum and maximum values. d’ (odor detection sensitivity) was calculated as: \( Z(\text{hit rate}) - Z(\text{false alarm rate}) \) (z = z-score). Beta (response bias) was calculated as: ordinate for false alarm rate – ordinate for hit rate.

Results

Descriptive statistics for the main variables are shown in Table 1.

Table 1. Minimum, maximum, mean and standard deviation values for the variables age, d’, β, CSS, PSS-10, SCL-90 and SRH.

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>d’</th>
<th>β</th>
<th>CSS</th>
<th>PSS-10</th>
<th>SCL-90</th>
<th>SRH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>18</td>
<td>0.36</td>
<td>0.08</td>
<td>21.0</td>
<td>15</td>
<td>0.16</td>
<td>2</td>
</tr>
<tr>
<td>Maximum</td>
<td>55</td>
<td>2.80</td>
<td>12.8</td>
<td>68.0</td>
<td>26</td>
<td>1.53</td>
<td>5</td>
</tr>
<tr>
<td>Mean</td>
<td>27.9</td>
<td>1.36</td>
<td>2.12</td>
<td>50.8</td>
<td>19.2</td>
<td>0.64</td>
<td>3.0*</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>8.35</td>
<td>0.68</td>
<td>3.39</td>
<td>11.5</td>
<td>2.71</td>
<td>0.39</td>
<td>1.0**</td>
</tr>
</tbody>
</table>
Correlation coefficients and results from significance testing are given in Table 2. The results showed that there is a strong tendency towards statistical significant correlations (p=0.051) between d´ and both PSS-10 and SRH. There is also a slight tendency towards a significant correlation (p=0.094) between d´ and CSS. For further illustration, scatter plots showing the relation between scores on the CSS, PSS-10, SCL-90 and SRH, on the one hand, and d´ and beta, on the other hand, are depicted in Figures 1 and 2, respectively.

Table 2. Spearman correlation (two-tailed) for SRH and Pearson correlation (two-tailed) coefficients for CSS, PSS-10 and SCL-90.

<table>
<thead>
<tr>
<th>CSS</th>
<th>PSS-10</th>
<th>SCL-90</th>
<th>SRH</th>
</tr>
</thead>
<tbody>
<tr>
<td>d´</td>
<td>-0.358&lt;ns</td>
<td>-0.412&lt;ns</td>
<td>-0.237&lt;ns</td>
</tr>
<tr>
<td>β</td>
<td>-0.099&lt;ns</td>
<td>-0.189&lt;ns</td>
<td>0.108&lt;ns</td>
</tr>
</tbody>
</table>

Discussion

The purpose of the present study was to examine if response bias (beta) and sensitivity (d´) in odor detection correlate with CI, stress, distress and self-rated health. For detection sensitivity there were tendencies of significant correlations with CI, stress and self-rated health. The individuals who were high in CI, stress and who generally felt poorly had a lower sensitivity. In accordance with the present work, a prior study has shown that individuals who are intolerant to noise are more likely to have poor hearing detection sensitivity (Anari, Axelsson, & Eliasson, 1999). Additionally, one might speculate whether individuals who are odor-sensitive tend to feel smells worse. It is also quite possible that these tendencies of correlations in the sample are not representative for the general population. The result also showed that detection sensitivity correlated with stress, such that individuals who are high in stress are low in detection sensitivity. It is possible that participants are very stressed at the test occasion, have more difficulties performing the detection task due to being less able to focus on the actual task. Thus, individuals who are high in CI are likely also to be high in stress (Sorg & Prasad, 1997).

*Median, **Interquartile range, CSS = Chemical Sensitivity Scale, PSS-10 = 10-item Perceived Stress Scale, SCL-90 = 90-item Symptoms Checklist, SRH = Self-Rated Health.
Figure 1. Scatter plots showing the correlation between $d'$ and scores on the CSS, PSS-10, SCL-90 and SRH.
Figure 2. Scatter plots showing the correlation between beta and scores on the CSS, PSS-10, SCL-90 and SRH.

The other part of the result showed that there were no correlations between beta and the variables; CI, stress, or self-rated health, which could probably depend on many things. For example, that there in fact is no correlation between beta and the variables in the population. It may also be explained by low statistical power due few participants considering that correlational analysis was applied and/or not enough sensitive ways to measure these variables. If we would have had very sensitive measuring methods, e.g. presented significantly larger number of stimuli, providing more stable data for the beta measurement and had twice as many individuals then we would have gotten more statistical power. Another possible for non-significant correlations regarding beta is that a large part of the participants consisted of relatively wealthy individuals, which limits the variability in the variables CI, stress, PSS or SRH. CI in relation to response bias speaks against continued research, since it has not shown any tendency.
Strengths of the current study include that well-established measuring instruments were used. For example, it is common in the research community to use the PSS and SCL-90, as they are reliable and well-known instruments. A further strength is that no participants discontinued the study, and no participant reported that the exposure resulted in excessive discomfort. The study has limitations which should be recognized. One such limitation is that my group was homogeneous, which may have had an impact on the results, and that a more heterogeneous group might have provided better understanding for the studied associations. In addition, the small sample size meant that the study had limited statistical power. Another limitation of the study is that I used a convenience sample, which limits the representativeness. A weakness of the actual test situation may have been that more than one test leader tested the participants. A final limitation of this study could be that for some individuals became sensitive while filling out the questionnaire. It might have brought thoughts about how they actually are living their lives, such as “am I stressed out” and “do I really feel good?”.

For further research, it is desirable to develop a broader measurement method to discern more aspects that affect the olfactory sensitivity of individuals, which might lead to results that are relatively consistent with previous research. Furthermore, it would be interesting to do further research about this, especially when the data has shown tendencies of correlations. In conclusion, the results from this study shows interesting tendencies and therefore it seems to be relevant for continued study of the associations with larger sample size. CI in relation to d’ suggests that CI cannot be explained by poor detection capability.

References


Appendix A

SIGNALDETEKTIONSTEST RJ

ID:

Gör såhär:

Sitt framför deltagaren med flaskorna gömda så att hen inte ser dem. Förklara att uppgiften är att avgöra om flaskan innehåller ett luktämne (n-butanol), eller bara vatten. Ge deltagaren luktflesken 6 och säg att det är denna lukt hen ska försöka identifiera.

Presentera varje flaskan enligt raderna i tabellen. 12 är den svagaste koncentrationen. 6 är den starkaste. B står för blank. Vänta 2 min efter var 14:e presentation.

Om deltagaren svarar ”ja”, markera den aktuella cellen med en ring (O). Om deltagaren svarar ”nej”, markera den aktuella cellen med ett kryss (X).

Kom ihåg: alternera mellan flaskorna med vatten (B) så att de inte värms mer än andra.

<table>
<thead>
<tr>
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<tr>
<td><strong>Svep1</strong> →</td>
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<td>B</td>
<td>B</td>
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<td>11</td>
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<td>10</td>
<td>11</td>
<td>8</td>
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Flaskpresentation

1. Presentera flaskan
2. Starta timer
3. Notera svaret
4. Ställ tillbaka flaskan
5. Ta upp ny flaskan
6. När timer når 20, gå till 1