Stroop Facilitation in Tinnitus Patients: An Experiment Conducted via the World Wide Web

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ABSTRACT

Cognitive mechanisms have been proposed to play an important role in tinnitus. In the present study, tinnitus participants were administered an emotional Stroop test via the Internet, incorporating words related to tinnitus concerns. In line with previous research using this Web-based version of the emotional Stroop test, faster color naming was demonstrated for concern-relevant words relative to neutral words. The present results thus provided support for a role for cognitive factors that are important for the understanding of tinnitus. However, future research is warranted in order to clarify the precise mechanisms involved in tinnitus-related Stroop effects.

INTRODUCTION

Tinnitus is characterized by the perception of noise in one or both ears in the absence of external stimulation.1 Tinnitus noises are described variously as ringing, buzzing, whistling, or humming, and the condition is often also associated with some hearing deficits. The severity and tolerance of tinnitus may vary considerably from individual to individual. However, no objective measure of tinnitus is currently available.2 There are many theories about the causes of tinnitus, but the precise mechanisms that produce the condition, and in particular annoying tinnitus, are still not fully understood.3 Consequently, available treatment interventions typically do not provide a cure for tinnitus, although they can help make the condition more manageable. Cognitive behavioral approaches emphasize the way in which thoughts about tinnitus influence the ability to cope with the condition.4 Therapeutic strategies often involve identifying and challenging unhelpful thoughts about tinnitus, directing attention away from tinnitus and learning how to cope with the stress produced by tinnitus. Research suggests that cognitive behavior therapy is effective in reducing tinnitus-related distress.5 There has, however, not been much research done on the cognitive mechanisms involved in tinnitus.

Researchers investigating the influence of cognitive mechanisms in emotional disorders have adapted paradigms from experimental cognitive psychology. The most popular of these has probably been the emotional Stroop task.6 In this task, participants are presented with words related to emotional concerns and neutral words printed in different colors. They are instructed to ignore the meaning of the words and to simply report the color in which each word is printed. Delayed color naming of words related to emotional concerns of participants relative to neutral words is proposed to indicate preferential allocation of attentional resources toward the emotionally salient information.7 Such Stroop interference effects have been...
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found in a number of emotional disorders, such as, generalized anxiety disorder, social phobia, and eating disorders. Stroop interference has also been found in patients with chronic pain.

Although individuals with emotional disorders, chronic pain patients, and individuals with tinnitus may differ in many important ways (e.g., physical mobility not affected by tinnitus, communication often more difficult for tinnitus patients because of hearing impairment), they tend to share a feature of preoccupation with information specific to their concerns. In a study by Andersson et al., the emotional Stroop test was thus used to investigate attentional bias toward words related to concerns of patients with tinnitus (e.g., peep and tones). A specific delay in color naming of words related to tinnitus concerns was, however, not demonstrated. One explanation offered by these investigators for the absence of a specific Stroop interference effect for tinnitus-related words in tinnitus patients was the presence of tinnitus itself. Previous research suggests that the presence of an object relevant to emotional concerns, for example, a snake for a snake phobic, may reduce emotional Stroop interference. This proposed explanation for this effect is that, when anxious, participants may increase their effort in color naming and therefore compensate for the interference caused by the meaning of the words. In the case of tinnitus, when the participant is present in a silent environment (i.e., the test room), hearing tinnitus might have caused anxiety and hence reduced any potential interference effect from the tinnitus words. In real life (outside the laboratory), tinnitus is often masked by environmental sounds (such as music), but attracts attention in silent environments.

The development of the Internet has provided a new method of data collection that offers effective presentation of standardized and controlled stimuli, immediacy of data entry, and accuracy in measurements of response time. In a study by Andersson et al. (unpublished data), an emotional Stroop task, adapted for social phobia, was converted into a Web page and administered via the Internet. Responses were made with mouse clicks on response buttons, which results in delayed response times compared to the usual voice-key/space bar press methodology. On the other hand, using mouse clicks is likely to have resulted in more precise measurement, with fewer errors (in contrast to the voice key methodology in which errors easily occur). In contrast to the expected Stroop interference effect found for social threat words in participants who performed a standard emotional Stroop task with oral responses and pressing a space bar, participants performing the Web-based emotional Stroop task showed a facilitation effect where words related to social threats were color named more quickly than neutral words. As expected, response times were also found to be longer overall on the Web-based Stroop version, suggesting that the process of indicating color choice via a manual response was more time consuming in this version compared with the standard emotional Stroop version in which a verbal response (and space bar press) was made. This was, in turn, proposed to indicate that color responding on these two versions occurred at different stages in information processing, with the Web-based Stroop occurring in a later time window. Results were interpreted as support for a vigilance-avoidance hypothesis, stating that initial vigilance toward threat relevant information (traditional Stroop) is followed by strategic attempts to avoid such information (Web-based Stroop). Participants performing the Web Stroop task were thus proposed to have been beyond the stage in information processing, where initial attentional bias occurs during color responding, in turn, enabling them to adopt strategic avoidant processing. The best way to accomplish such avoidance would be to color name stimuli as quickly as possible, making the word disappear from the computer screen. While the delay in responding caused by moving the mouse to the response buttons on the screen is the most parsimonious explanation for this effect, it does not in itself explain the reversal of the Stroop effect from interference to facilitation, which is likely caused by a psychological factor (e.g., stages of information processing).

In the present study, a Web-based version of the emotional Stroop task was employed similar to that utilized by Andersson et al. (unpublished data), but adapted for tinnitus. Based on the findings by Andersson et al. (unpublished data), individuals with tinnitus were expected to color name words related to tinnitus more quickly than neutral words. However, since the results from the study by Andersson et al., using a standard emotional Stroop task, did not support a specific Stroop effect for tinnitus-related words in patients with tinnitus, variables that have been found to influence the Stroop effect were manipulated in order to examine whether a specific effect for tinnitus words could be found under certain conditions. Based on findings from previous research indicating that the presence of an emotional object can reduce the Stroop effect, noise level was manipulated. Participants were thus randomly allocated to perform the Stroop task in a silent environment or in a noisy environment (with the potential to mask their
tinnitus), with greater Stroop effects expected for participants in the noise condition when tinnitus was less audible. Moreover, previous research suggests that varying the proportion of words to non-words influences the Stroop effect, where enhanced interference has been found for emotionally relevant words when the ratio of words to non-words is low.\textsuperscript{16} In line with these findings, the ratio of words to non-words was reduced.

**MATERIALS AND METHODS**

**Participants**

One-hundred and twenty-one individuals with tinnitus were contacted about the present study via e-mail. These individuals were all on a waiting list for treatment at the Department of Audiology at the University Hospital in Uppsala, Sweden. For participation, they were required to have access to a PC and Internet connection. Fourteen individuals experienced computer problems and thus never completed the test, whereas two individuals only had access to Macintosh computers and one individual declined to participate. A total of 104 individuals with tinnitus took part in the present study. The mean age of these participants was 45.4 years (SD = 15.6; range, 17–76 years), of which 44\% were male. Sixty-nine participants reported hearing loss, of which 10 had loss of hearing in the left ear, 16 in the right ear, and 43 in both left and right ears. The mean duration of tinnitus was 10.1 years (SD = 11.00). For the purpose of comparison, 21 non-tinnitus participants with normal hearing, who were friends of the participants in the tinnitus group, served as control participants. Mean age was 37.8 years (SD = 15.8; range, 18–71 years), of which 53\% were male. All participants, both in the control group and in the tinnitus group, reported normal color vision.

**Materials**

*The Stroop test.* The Stroop test used in the present study was converted into a Web page and administered via the Internet. This test was developed by Icon Medialab and is based on Macromedia flashplayer (version 6). The test was run via the Internet, but time measurement was done on the computer used in order to be able to measure response latency time in milliseconds independent of the network connection. The program was written in Active Server Pages (version 3.0), and a MySQL database (version 3.23.58) was used to store data.

**Stimulus words.** Stimuli used in the Stroop task comprised of six words related to tinnitus concerns (e.g., buzz), six neutral words (e.g., crop), and strings of xxxx. The tinnitus-related words were drawn from previous research into tinnitus concerns.\textsuperscript{12} Tinnitus-related and neutral words were matched for number of syllables, word length, and frequency of usage based on Swedish language norms.\textsuperscript{17} A complete list of words used in the Stroop task is found in the Appendix.

**Self-report questionnaires.** In order to assess tinnitus-related distress, participants with tinnitus were asked to complete the 26-item Tinnitus Reaction Questionnaire (TRQ).\textsuperscript{18} Levels of anxiety and depression were assessed in both tinnitus participants and control participants by administering the 14-item Hospital Anxiety and Depression Scale (HADS),\textsuperscript{19} divided into HADS-anxiety (HADS-A) and HADS-depression (HADS-D).

**Procedure**

Tinnitus participants and control participants were randomly allocated to a noisy condition or a silent condition. Participants in the noisy condition were asked to surround themselves with noise during the Stroop test from, for example, radio, TV, or noisy traffic through an open window. Participants in the silent condition were instead instructed to create an environment as quiet as possible during the Stroop test. Participants were tested individually on the Stroop test. Words were presented separately in lowercase letters against a black screen in one of four colors: red, blue, green, or yellow. Each word was presented once in each color and strings of xxxx were presented 80 times, producing a total of 128 trials for each participant. Order of presentation of words, strings of xxxx, and colors was randomized for each participant. Participants were instructed to ignore the meaning of the words and to focus on the colors in which the words were printed. Four gray boxes, upon which each of the color names were printed in black ink, were displayed below the area of word presentation. Participants were instructed to indicate their color naming choice by clicking on the box representing the color in which the word was displayed as quickly as possible without compromising accuracy. The location of each color option was randomized for each participant. Furthermore, in order to
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Since sample size varied greatly between tinnitus participants and normal control participants, separate ANOVA’s were conducted for these two participant groups. In order to test the hypothesis that participants with tinnitus would show greater delays in color naming tinnitus-related words compared to neutral words, a mixed 2 x 3 ANOVA was carried out with noise condition (noise versus no noise) as the between-subjects factor and stimuli type (tinnitus-related words, neutral words, and strings of xxxx) as within-subject factor. There was no interaction between noise condition and stimuli type ($F(2,204) = 0.37, p = 0.54$) and no main effect of noise condition ($F(1,102) = 0.70, p = 0.49$). There was, however, a main effect of stimuli type ($F(1,102) = 38.9, p < 0.001$). Using the Tukey-Kramer test as a post hoc procedure, tinnitus participants were found to color name the tinnitus words faster than the control words. Strings of xxxx were color named faster than both tinnitus words and neutral words. There was no difference between tinnitus and control words.

Figure 1 presents mean response times for tinnitus participants on the Stroop task for tinnitus-related words, neutral words, and strings of xxxx, in both the silent and the noisy condition. Mean response times for control participants on the Stroop task, for the silent and the noisy condition combined, was $1,148.2 (340.6)$ msec for tinnitus-related words.
words, 1,132.7 (323.5) msec for neutral words, and 1,070.2 (279.2) msec for strings of xxxx.

DISCUSSION

Results revealed, in line with the findings obtained by Andersson et al. (unpublished data), that stimuli related to specific concerns of participants were color named faster than neutral stimuli on the Web based version of the emotional Stroop task. The hypothesis that participants with tinnitus would be faster to report the color of words related to tinnitus than the color of neutral words was thus supported. The findings add to the growing literature investigating cognitive aspects of tinnitus, which has theoretical importance for the understanding of why a proportion of persons with tinnitus (2/10) develop severe problems whereas most do not. There was no difference between tinnitus participants performing the Stroop task in a noisy or silent environment, providing no support for the hypothesis that a greater effect would be found in the silent condition compared to in the noisy condition. This finding, in turn, suggests that the presence of tinnitus itself may not influence Stroop performance, although the sound manipulation outside the laboratory might have been too weak.

The present findings may, in line with Andersson et al. (unpublished data), be interpreted as support for the vigilance-avoidance model of information processing, which argues that initial vigilance toward information of emotional concern is followed by subsequent attempts to avoid such information. As mentioned previously, Andersson et al. (unpublished data) proposed that color responding in the Web-based Stroop version occurred at a later stage than in the standard emotional Stroop task, and as this implies later stage of information processing, participants will have more time to adopt strategic avoidant processing. However, since only the Web-based version of the Stroop task was used in the present study, we can only speculate about whether attentional bias would be found on a standard emotional Stroop task in participants with tinnitus. Considering that Andersson et al. did not find Stroop interference for tinnitus-relevant words in patients with tinnitus on a standard emotional Stroop task, a pattern of vigilance-avoidance responding does, however, not seem to be a plausible explanation of the present results. Furthermore, the vigilance-avoidance model was primarily formulated to account for how individuals high in anxiety initially direct attentional resources toward threat relevant material and subsequently try to avoid such threat to reduce anxiety. We are not aware of any studies that have extended this thinking to health-related concerns in somatic patients (e.g., cancer).

An alternative explanation refers to the possibility that tinnitus is associated with cognitive bias only at late stages of information processing and not early stages. Researchers within the domain of cognitive processing and emotional disorders suggest that different emotional disorders are associated with bias at distinct levels of information processing. Anxiety disorders, for example, have been found to be associated with bias at early automatic stages of information processing, whereas depression has been found to be associated with bias at later, more elaborative, stages of information processing. If tinnitus is associated with cognitive bias at later stages of information processing, it might thus be plausible to expect Stroop effects only when the process of color responding is manipulated as to be more time-consuming or occur later. However, it may be argued that an interference effect would then be expected rather than facilitated. Alternatively, low levels of anxiety, as demonstrated in tinnitus participants in the present study, may be associated with enhanced ability to orient processing resources away from material of concern.

It is further possible that the present findings can be attributed to the changes made with regard to proportion of words to non-words, where Stroop interference would also be demonstrated on a standard emotional Stroop task if a low ratio of words to non-words was adopted. As mentioned previously, increased Stroop interference has been found when the ratio of words to non-words has been low. It is possible that such augmenting effects are also found when facilitation occurs, as in the present study. However, Amir et al. hypothesized that the enhanced Stroop interference effect found in their study for participants with social phobia was due to that the low frequency of words to non-words relaxed tendencies to try and strategically inhibit automatic attention toward socially threatening information. An alternative explanation might be that presenting emotionally relevant words less frequently than other stimuli inhibits habituation of the emotional stimuli, leading to enhanced Stroop effect regardless of its direction. It is thus possible that Stroop effects in tinnitus are of small magnitude where stimuli proportions must be manipulated in order to prevent habituation for these effects to be seen.

A limitation of the present study refers to the great difference in sample size between tinnitus participants and control participants. Furthermore, it may not be possible to attempt to explain results...
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obtained in the present study by generalizing from theories adapted for emotional disorders. Nevertheless, findings from the current study indicate that cognitive processes play a role in tinnitus, where information relevant to tinnitus concerns is processed differently than neutral information. Future research is, however, needed in order to disentangle the role played by the various factors involved in tinnitus-related Stroop effects. One important direction for future research is to investigate the influence of varying proportions of different stimuli types. It would, for example, be interesting to investigate whether Stroop interference can be found in tinnitus patients using a standard emotional Stroop task when the ratio of words to non-words is low. It would further be interesting to see whether facilitation effects are found on the Web version of the Stroop task when the ratio of words to non-words is high. Further research is also needed in order to clarify whether tinnitus is characterized by cognitive bias at later, more elaborated, conceptual stages in information processing, or early automatic stages. One way to accomplish this may be to assess whether emotional disorders associated with cognitive bias at elaborate stages of information processing are associated with Stroop facilitation, or interference, on versions of the Stroop task where time duration of the process of color-responding has been manipulated as to reflect bias at later stages of information processing.

Another limitation of the study refers to the way that we collected response times, as we cannot guarantee that response times did not differ, at least to some extent, across different processor speeds. Hopefully, future computer applications of response time measurements will be able to handle this better.

In summary, research into the role of cognitive mechanisms in tinnitus is in its infancy where many questions remain unanswered. However, results of the present study indicate that cognitive mechanisms may play an important role in tinnitus where words related to tinnitus relevant concerns and neutral words are processed in different ways. Future research is, however, required in order to clarify what mechanisms are involved in Stroop effects in individuals with tinnitus. Future research is also warranted to investigate the influence of varying time duration of color responding on versions of the emotional Stroop task.

ACKNOWLEDGMENTS

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APPENDIX: TINNITUS-RELEVANT WORDS AND NEUTRAL WORDS USED IN THE STROOP TEST WITH SWEDISH TRANSLATIONS IN PARENTHESIS

<table>
<thead>
<tr>
<th>Tinnitus words</th>
<th>Neutral words</th>
</tr>
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<tbody>
<tr>
<td>Howling (Tjut)</td>
<td>Crop (Säd)</td>
</tr>
<tr>
<td>Peep (Pip)</td>
<td>Goat (Get)</td>
</tr>
<tr>
<td>Test-pattern (Testbild)</td>
<td>Barley-grain (Korngryn)</td>
</tr>
<tr>
<td>Piercing (Vasst)</td>
<td>Cow (Ko)</td>
</tr>
<tr>
<td>Tone (Toner)</td>
<td>Species (Arter)</td>
</tr>
<tr>
<td>Buzz (Brus)</td>
<td>Harvest (Skörd)</td>
</tr>
</tbody>
</table>

REFERENCES


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