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Reliability of two versions of the dot-probe task using photographic faces

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Abstract

The dot-probe task developed by Macleod, Mathews and Tata (1986) is a measure of attentional bias. Recent developments of the task have favoured the use of human faces as stimuli, however, results from this task have been inconsistent. In 2005, Schmukle published very poor reliability estimates for two versions of the dot-probe task using words and situational images as stimuli. The present study tested the reliability of two versions of the test, using photographs of human faces. One version was similar to previous research, while the other was a modification designed to meet a potential methodological issue. Results indicate that both versions tested were unreliable and therefore unsuitable for individual differences research. When considered as a group, however, participants showed consistent attentional bias towards emotional faces in the task similar to previous research, while habituation effects were found in the modified task. This suggests that the two tasks may be used in between-group designs to investigate different aspects of attention to emotional faces.

Key words: attention; dot-probe, reliability; emotional faces; reaction time

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The dot-probe task was originally developed by Macleod, Mathews and Tata (1986) based on the observation that people respond faster to probes when they are presented inside the field of awareness rather than outside of it. Therefore, when presenting participants with stimuli in separate spatial locations prior to the onset of the probe, the difference in reaction time between congruent trials (stimulus and probe are in the same location) and incongruent trials (stimulus and probe are in different locations) is believed to indicate which location the participant was attending to at the moment of response (Chen, Ehlers, Clark & Mansell, 2002). This difference is called a *bias index*, and extreme scores on the index are thought to reflect attentional bias: the propensity to be more or less attentive of certain classes of salient stimuli (ibid.).

Attentional bias is a cornerstone in two influential cognitive models of social anxiety, namely those of Clark and Wells (1995) and Rapee and Heimberg (1997), where it is hypothesized to be a maintaining factor. According to Clark and Wells, avoidance of threatening social cues (such as angry facial expressions) is a strategy to reduce or control the anxiety of people with social phobia experience, when they are in a social situation. Rapee and Heimberg agree with Clark and Wells that avoidance is part of the attentional bias in social anxiety, but they also maintain that socially anxious individuals show vigilance for threatening cues. Reviewing this distinction of avoidance vs. vigilance, Schultz and Heimberg (2007) found that the dot-probe paradigm produced inconsistent results. Specifically, studies have found attentional bias consistent with both vigilance and avoidance in socially anxious participants when compared to controls, as well as no difference between groups. This inconsistency is true for clinical groups (vigilance: Sposari & Rapee, 2007; avoidance: Chen et al., 2002; no difference: Gotlib et al., 2004) as well as groups with subclinical social anxiety (vigilance: Mogg & Bradley, 2002; avoidance: Mansell, Clark, Ehlers & Chen, 1999; no difference: Bradley et al., 1997). Inconsistent results have also been reported when the design involved a threat condition such as a public speaking task (no differences: Pineles & Mineka, 2005; avoidance: Mansell et al., 1999; vigilance: Sposari & Rapee, 2007).

Two explanations have been proposed that may account for this discrepancy. One is the "vigilance-avoidance" hypothesis (e.g. Weierich, Treat & Hollingworth, 2008), which theorizes that initial automatic vigilance for threatening stimuli is followed by later strategic avoidance. In partial support of this hypothesis, a dot-probe study by Stevens, Rist and Gerlach (2009) comparing social phobics with controls showed vigilance for angry faces at 175 ms, but not at 500 ms, while Mogg, Philippot and Bradley (2004) found vigilance for angry faces at 500 ms, but not at 1250 ms, in their dot-probe study comparing social phobics and controls. This would suggest that relatively shorter exposure durations produce vigilance, but that attentional bias changes at durations around 500 ms and longer. Other research has found that exposure durations of 100 ms produce attentional vigilance, while durations of 500 ms do not (Cooper & Langton, 2006; Holmes, Green & Vuilleumier, 2005). The outstanding question is whether this fast initial vigilance at 100 ms is maintained, disappears, or reverts into avoidance at 500 ms, which is the typical exposure duration used in dot-probe tasks. As reviewed above, the dot-probe literature supports all three possible outcomes.

The other explanation for the inconsistency of findings was recently offered by Schmukle (2005), who hypothesized that the reliability of the dot-probe task may not be adequate. He tested this prediction in two different versions of the task: one with words as stimuli and one with situational images. In the word task, both 100 ms and 500 ms exposure durations were employed, whereas the picture task used a 500 ms duration only. All versions showed very poor reliability in two university student populations. Importantly, Schmukle did not include photographs of human faces as stimuli. More recent dot-probe tasks have favoured the use of faces over words given their presumed higher ecological validity (Gilboa-Schechtman, Foa & Amir, 1999). So far, at least 17 published dot-probe studies investigating attentional bias in social anxiety have used faces (systematic searches in the PubMed and PsychINFO databases). It is therefore critical that the reliability of the dot-probe task with facial stimuli is investigated.

One explanation for Schmukle's (2005) negative results could be that the dot-probe task is not sensitive enough to reveal consistent responses within nonanxious groups. While this would ultimately entail that the task cannot be used to test individual differences in nonanxious participants, between-subject effects can still be obtained, if control groups consistently show no attentional bias, or at least bias in the same direction (i.e. consistent with either avoidance or vigilance). In a meta-analysis of 15 picture dot-probe studies by Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg and van IJzendoorn (2007), there was indeed no significant attentional bias in nonanxious participants, however, studies using faces as stimuli report effects even in nonanxious groups (Cooper & Langton, 2006; Bradley et al., 1997). This inconsistency is problematic for between-subject designs. Therefore, examining the reliability of the dot-probe task with facial stimuli in a nonanxious population is important.

One dot-probe study that simultaneously used an eye-tracking apparatus, revealed a tendency of some participants to ignore the facial stimuli and initiate their search only when the probe appeared (Bradley, Mogg & Millar, 2000). The problem with such a strategy is that if participants do not overtly shift their attention, attentional bias may be reduced as a consequence. One possible way of assuring that participants actively attend to the faces is to retain them within the visual field after onset of the probe (typically, the faces disappear the moment the probe appears). When the offset of the faces no longer serves as a cue for probe onset, participants may be forced to initiate their search while the faces are visible.

Finally, an interesting aspect that has been somewhat overlooked in the literature is habituation to the facial stimuli over the course of the task. One research group has suggested that an aspect of anxiety may be lack of habituation to threatening stimuli (Bradley, Mogg, White, Groom & de Bono, 1999; Garner, Mogg & Bradley, 2006). If this hypothesis is true, habituation to the threatening faces across the multiple presentations that the dot-probe task entails might be expected in nonanxious participants. This hypothesis is supported by research that shows habituation of the metabolic response in the amygdala to continuous presentations of threatening faces (for a review, see Zald, 2003).

The present study will investigate four important aspects of the dot-probe task and attentional bias in a nonanxious population, using standardized photographs of human faces as stimuli. First, the reliability of the dot-probe task is investigated. This is a crucial first step towards determining the usefulness of this design in research on attentional bias. Second, by using exposure durations of 100 ms and 500 ms, the time-course of attentional bias is examined. Specifically, the study seeks to replicate the pattern of early vigilance followed by later avoidance reported by Cooper and Langton (2006). Third, a modified version of the dot-probe task in which the faces remain visible after the onset of the probe is introduced. This version may ensure that participants actively attend to the faces during the task as explained above. Fourth, habituation effects will be examined by testing the stability of attentional bias within and between sessions. It is expected that the nonanxious population in the present study will show habituation to the threatening faces in both cases.

An important change was added to the present design. The visual angle (the relative distance between the two stimuli) varies quite a lot between dot-probe designs with most studies reporting a visual angle of 4-9 degrees. However, basic visual research has shown that a visual angle of 11 degrees is the optimal horizontal distance for detection of stimuli using only eye rotations, whereas angles wider than 15 degrees generally require supporting head rotation (Hallett, 1986). This optimal distance may maximize the time required to switch attention between the two stimulus locations, thus increasing the sensitivity of the task.

The dot-probe task has been used in at least 100 published studies so far (Bar-Haim et al., 2007; systematic searches conducted in PsychInfo and PubMed) and its influence in shaping our current knowledge of attentional bias in a variety of disorders can hardly be underestimated. It is thought provoking though, that the reliability of the task was not tested more thoroughly before it was so widely applied.

Method

Purpose

The purpose of the present research is to test the reliability of two versions of the dot-probe task. A *standard* version, similar to the one used in more recent dot-probe studies, and a *modified* version that may have specific utility in nonclinical samples.

Participants

Thirty-nine participants (21 female, 18 male) were recruited at Aarhus University. Demographic data can be seen in Table 1. This number of participants was sought, since the picture task in Schmukle's (2005) study featured 40 participants. The statistical power to

Table 1:
Demographic and Questionnaire Data by Gender

	Males (n = 18)		Females (n = 21)			Test-retest	
	M	(*SD*)	*M*	(*SD*)	*p*	*r* (males)	*r* (females)
Age	27.06	(3.9)	30.29	(7.9)	.122		
Interval (in days)[a]	8.39	(2.3)	8.38	(2.1)	.991		
BDI-II 1st session	3.72	(3.6)	4.24	(3.7)	.606		
BDI-II 2nd session	2.56	(3.2)	4.05	(4.5)	.148	.743	.869
SIAS 1st session	15.83	(8.1)	14.62	(10.8)	.379		
SIAS 2nd session	14.39	(8.2)	15.43	(12.1)	.749	.936	.967
STAI 1st session	27.56	(7.9)	31.17	(7.7)	.078		
STAI 2nd session	26.28	(7.0)	29.95	(7.1)	.073	.579	.434
B-FNE 1st session	31.22	(8.1)	33.79	(7.6)	.410		
B-FNE 2nd session	29.17	(8.4)	30.90	(8.2)	.426	.907	.872

[a] In comparison, the test-retest interval in Schmukle's (2005) study was 7 days.

find a significant effect ($\alpha = 0.05$) for a true correlation of at least $\rho = 0.50$ was 0.955, which is similar to the power reported in Schmukle's (2005) study.

Questionnaires

The following questionnaires were used for the study: The state form of the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Luschene, Vagg & Jacobs, 1983); Beck's Depression Inventory-II (BDI-II; Beck, Steer & Brown, 1996); the Brief Fear of Negative Evaluation (B-FNE; Leary, 1983); and the Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998). All questionnaires were backtranslated Danish versions.

Photographic faces

For all trials, angry, happy and neutral faces taken from the NimStim Face Stimulus Set (Tottenham et al., 2009) were used. The advantages of the NimStim set are many: The photos are contemporary, actors portray each emotion in at least two different ways – one with their mouth open and one with their mouth closed – and the set features a high number of different models. Specifically, the female models 01f, 05f, 07f, 08f, 09f, 10f and the male models 20m, 22m, 23m, 27m, 34m and 36m were used for all tests. All photos were resized to 253x325 pixels (screen size: width = 7.5 cm, height = 9.5 cm) and their backgrounds were changed to a light grey.

The standard dot-probe task

The task used in this study was programmed and run using DirectRT (EmpiriSoft Corporation, New York). A trial consisted of a pair of photos of the same model. Each pair was made up of either an emotional (angry or happy) and a neutral expression, or two neutral expressions. When both expressions were neutral, one had an open mouth and the other had a closed mouth to ensure that the expressions were not completely identical. Since the neutral expressions are presented more frequently throughout the task than any of the emotional expressions, including two versions of the neutral expression for each model might reduce habituation to these expressions. All trials were arranged into eight blocks of 36 presentations each, totalling 288 trials. The blocks contained equal numbers of angry-neutral, happy-neutral and neutral-neutral pairs as well as equal numbers of male and female models. The order was randomized in each block. During presentation, participants saw a centered, white fixation cross on a black background for 1500 ms, followed by 200 ms of blank screen. A pair of faces was then visible for either 100 or 500 ms depending on the experimental condition (see procedure below), after which it was immediately replaced by a probe. The probe was a blue, 22-point bold letter (an E or an F) and participants pressed one of two keys clearly labelled E or F in response, using a customized response box (DirectIN High Speed Button-Box; EmpiriSoft Corp.) with the keys placed one above the other. The letter remained visible until participant response. In half the trials, the probe appeared on the left side of the screen and in the other half it appeared on the right side. When the letter appeared in the location of the emotional face, this was a congruent trial, and when it appeared in the location of the neutral face, it was an incongruent trial. After 500 ms of blank screen, the next trial commenced.

The modified dot-probe task

This task was identical to the standard task described above save for one key aspect: When the probe appeared, the faces stayed visible on the screen until response. The probe thus appeared in front of either the emotional face (congruent condition) or the neutral face (incongruent condition) after 100 or 500 ms depending on condition.

Procedure

Upon arrival at the laboratory, the participant was left alone to fill in the questionnaires. The researcher would then sit next to the participant for the remainder of the session to make sure that the participant followed procedure, but also to provide feedback if needed and to initiate the various tests. Following a short computerized introduction, which included 10 trials with presentations of neutral faces only (model 18F was used) participants completed the different versions of the task in counterbalanced order. Participants would sit comfortably with their heads approximately 1 m from a 19” widescreen TFT monitor set at 1280x1024 resolution. Participant movement was not restricted. All trials were presented on a black background. Participants were instructed to respond as quickly as possible while also avoiding errors. Each block of trials was separated by a short pause. After an interval of 1-2 weeks, participants would return for the second session. The procedure was identical, only the introduction was omitted and participants were debriefed upon completion. Each session would take approximately an hour and was conducted in a relaxed atmosphere.

Results

Data preparation

All data were entered into SPSS version 15. Participant errors were recorded as missing data and accounted for 1.1% of all dot-probe trials. For each trial, if a participant’s reaction time was identified as an outlier by SPSS, it was changed to 1 ms higher or lower than the second-most extreme reaction time for that participant following recommendations by Tabachnick and Fidell (2001). Such outliers accounted for 2.4% of the data. The participant with the highest number of outliers, had a total of 54 (9.4 %) of his scores changed.

Questionnaires

Questionnaire data can be seen in Table 1. There were three missing items in total, which were replaced using the mean substitution function in SPSS. Since the questionnaire data were generally skewed, a Mann-Whitney test was used to analyze gender differences. As the only measure, the STAI showed a tendency towards significance with females scoring slightly higher than males. All questionnaires had sufficient test-retest reliability, save for the STAI, which is not meant to have good test-retest reliability (Spielberger et al., 1983).

Standard dot-probe results

Following the procedure for calculating the bias index (e.g. Schmukle, 2005), reaction times from congruent trials were subtracted from reaction times from incongruent trials and divided by 2. Means, standard deviations and reliability estimates for the bias indices from the standard dot-probe task are presented in Table 2. To estimate the internal reliability, split-half correlations and Cronbach's alpha were computed. To calculate Cronbach's alpha, all critical trials were combined into pairs based on facial expression. That is, a pair would for instance consist of one congruent angry male and one incongruent angry female face. Then a bias index was calculated for each pair, and pairs sharing the same expression were analyzed for consistency. Split-half reliability was calculated by simply correlating the first half of the trials with the latter half. None of the reliability estimates were significant (see Table 2).

To analyse bias scores, a repeated measures ANOVA was used with time (session 1 and 2) and valence of faces (angry, happy) as within-subject factors. None of the main effects or interactions was significant (all p's > .05). Following Cooper & Langton (2006), one-sample t-tests were used to investigate whether bias scores differed significantly from zero to indicate either avoidance or vigilance. Participants showed vigilance for angry faces in the 100 ms condition, but only during the first time of testing (1^{st} session: $t(38) = 2.336$, $p = .026$; 2^{nd} session: $t(38) = 1.113$, $p = .273$). The results for happy faces were the opposite: Participants showed vigilance for happy faces during the second time of testing only (1^{st} session: $t(38) = 1.819$, $p = .077$; 2^{nd} session: $t(38) = 4.559$, $p < .001$). In the 500 ms condition, all p's were significant, showing vigilance for both angry and happy faces (1^{st} session angry: $t(38) = 2.759$, $p = .009$; 1^{st} session happy: $t(38) = 3.497$, $p = .001$; 2^{nd} session angry: $t(38) = 4.123$, $p < .001$; 2^{nd} session happy: $t(38) = 4.038$, $p < .001$).

Modified dot-probe results

The bias index in the modified task was calculated in the same way as in the standard task. Means, standard deviations and reliability estimates can be seen in Table 2. All critical trials were combined into 11 happy and 12 angry pairs for each condition (100 ms or 500 ms). For the modified task, a single split-half correlation was significant, but this apparent consistency was not reflected by either alpha or test-retest estimates (see Table 2).

As in the standard task, bias scores were analysed with a repeated measures ANOVA. Again, main effects and interactions were non-significant (all p's > .05). One-sample t-tests were used to check for vigilance or avoidance. In the 100 ms condition, the only significant result was vigilance for angry faces during the first time of testing ($t(38) = 2.342$, $p = .024$; all other p's > .3). In the 500 ms condition, participants showed vigilance for angry faces during the second time of testing only ($t(38) = 2.473$, $p = .018$; all other p's > .1).

Table 2:
Means, Standard Deviations and Reliability Estimates for Bias Indices

Test condition	*n* = 39		Test-retest	Alpha[a]	Split-half
	M	(*SD*)	*r*	α	*r*
Standard 1st session					
100 ms happy	7.59	(26.1)		.272	.100
100 ms angry	9.03	(24.2)		.043	.174
500 ms happy	11.67	(20.8)		-.514	.208
500 ms angry	14.37	(32.5)		.021	-.054
Standard 2nd session					
100 ms happy	17.41	(23.8)	-.243	.191	.290
100 ms angry	4.07	(22.8)	.262	.188	-.050
500 ms happy	13.44	(20.7)	.068	-.285	-.088
500 ms angry	14.38	(21.8)	.198	-.518	-.176
Modified 1st session					
100 ms happy	12.73	(33.9)		.149	.136
100 ms angry	1.14	(32.1)		-.407	-.290
500 ms happy	7.97	(47.4)		.314	.143
500 ms angry	-3.73	(45.9)		-.085	.074
Modified 2nd session					
100 ms happy	1.85	(33.0)	.004	.307	.373
100 ms angry	-5.16	(35.9)	.062	-.114	-.044
500 ms happy	7.92	(36.8)	.122	-.581	.170
500 ms angry	16.38	(41.4)	.139	-.254	.065

[a] Cronbach's alpha

Questionnaires

Since the STAI showed low reliability as expected, it might be argued that the change in state anxiety scores between the first and the second session of testing is related to the change in bias index scores between sessions. To explore a possible relationship between state anxiety and attentional bias, change scores were calculated for bias indices for angry faces and for state anxiety, by subtracting the first session values from the second session values. The resultant change scores were then correlated. This did not produce any significant correlations (all *p*'s > .05), which suggests that change in state anxiety between sessions was unrelated to changes in attentional bias towards angry faces.

Age and gender effects

Repeated measures ANOVA's were used to test for effects of age and gender with gender of participant as between-subject factor, time and valence as within-subject factors, and age as covariate. No main effects or interactions were significant (all p's > .05).

Habituation

To test whether the bias indices for angry faces were reduced within or between sessions, a repeated measures ANOVA with exposure duration (500 and 100 ms), time (first and second half of each session) and session (first and second session) as within-subject factors was carried out. The standard test did not reveal any habituation effects (bias scores for angry faces were stable within and between sessions; all p's > .05), but the modified tests showed significant results. Specifically, the main effect of time and the interaction between exposure duration and session were significant (for time: $F(1,38) = 4.992$, $p = .031$; for duration x session: $F(1,38) = 5.684$, $p = .022$). Inspection of means (see Figure 1) revealed that the main effect of time was due to a reduction in bias scores within sessions, whereas the interaction between exposure duration and session was due to participants showing increased vigilance during the second session in the 500 ms condition only.

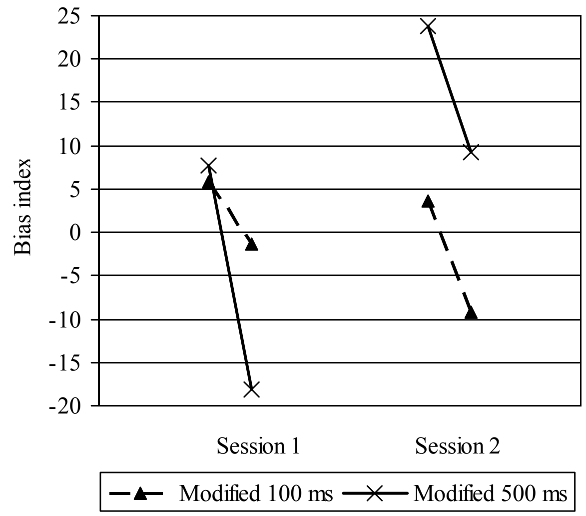

Figure 1:
Habituation to angry faces between the first and the second half of each session in the modified tasks

Discussion

The four versions of the dot-probe task examined in this study--the standard version with exposure durations of 100 ms and 500 ms and a modified version with exposure durations of 100 ms and 500 ms--did not show the required test-retest reliability or internal consistency. The modified version did show one significant split-half correlation, but Cronbach's alphas and test-retest correlations remained very low or even negative. Follow-up analyses indicated that the poor reliability was not due to changes in state anxiety between sessions.

In conclusion, there was no coherent relationship between attentional bias scores for individual participants between the two testing sessions. Although this entails that the dot-probe task presented here should not be used in individual differences research, it may still be useful for research between groups as long as the participants showed consistent bias scores (that is, either no bias at all or bias in the same direction). Investigating the bias scores, the standard test at 500 ms showed vigilance for emotional faces regardless of their valence. Furthermore, investigating habituation effects within and between sessions, the standard test at 500 ms showed that vigilance for angry faces was stable both within sessions and between sessions. This implies that, when considered as a group, nonanxious participants have stable, consistent scores on the standard 500 ms dot-probe task presented here. This particular task therefore appears suitable for research into group differences.

Contrary to these findings, vigilance was reduced within each session in both of the conditions in the modified task. This would make the modified dot-probe test presented here suitable for testing the hypothesis that socially anxious participants fail to habituate to threatening faces. Interestingly, attentional bias was not reduced *between* sessions, which indicates that the mean 8-day intersession interval used is sufficiently long for the emotional faces to regain their salience.

Confounders

The visual angle was deliberately increased in the present study, compared to earlier studies, which introduces the possibility that the findings do not generalize to the dot-probe task in general. Increasing the visual angle would appear to increase reaction times as expected (mean reaction times ranged from 749.5 ms to 793.4 ms in the standard version of the task, whereas reaction times in previous studies typically range from 400 ms to 650 ms). Although standard deviations and bias indices seem to be within the range of other dot-probe tasks testing healthy controls, the possibility that there are subtle differences in how the design affects attention processes can not be ruled out. However, in support of the generalizability of the present findings, they do replicate and extend those of Schmukle (2005).

Conclusion

The dot-probe design with photographic faces was found not to be reliable. This extends the findings of Schmukle (2005), who found poor reliability in nonanxious participants using words and situational images as stimuli. It is therefore recommended that until reliability has been firmly established, any results regarding individual differences originating from the dot-probe task should be interpreted with caution. An intriguing result in the present study is that the two dot-probe versions presented may be useful in between-group designs, investigating different hypotheses regarding attentional bias in social anxiety. Specifically, in the standard task at 500 ms, the group as a whole showed stable and consistent vigilance for emotional faces, in line with research showing that facial emotion captures attention in nonanxious populations (Palermo & Rhodes, 2007). This version may be useful for investigating effects of vigilance and avoidance to emotional faces in social anxiety, since previous research has not yet produced a more definite answer to this important question. In the modified task, when the faces remained visible, vigilance to angry faces was reduced within sessions consistent with quick habituation to threat in nonanxious populations (Zald, 2003). This version may therefore be suitable for investigating a possible failure to habituate to threatening faces in socially anxious individuals as proposed by Bradley et al. (1999).

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