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ORIGINAL RESEARCH

Is It Implicit Detection or Perception During Change Blindness?

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Purpose: Implicit detection differs from implicit perception. The former includes implicit registration, localisation, identification and comparison of an object. Implicit comparison is not necessary for implicit perception, and should not involve the identification or localisation of objects. While many studies have reported evidence of implicit detection in change blindness, they may, in fact, have only observed implicit perception. In this study, we aimed to find out whether there is implicit detection or perception during the change blindness period.

Methods: In Experiments 1 and 2, we used a simple change detection paradigm, coupled with a speeded attribute discrimination task. Reaction times (RTs) and accuracy of the participants were measured for the speeded attribute discrimination task. We compared differences in RT and accuracy of the invalid and congruent cue trials to find evidence for implicit detection. Invalid trials referred to stimuli where the appearance of the cue does not change, whereas congruent trials involved cued objects with the same attributes as that of the change object. In Experiment 3, a one-shot change detection experiment was conducted, where subjects were required to report whether the objects were the same or different as quickly as possible. We compared the differences in RTs between trials in which the stimulus exhibited a change but participants reported "same" (change blindness trails) and trials in which the stimulus exhibited no change and participants reported "same" (baseline trials), to find evidence for implicit perception.

Results: In Experiments 1 and 2, the difference in accuracy and RTs under invalid and congruent conditions was not significant. We did not observe a validity effect as evidence for implicit localisation or a congruency effect as evidence for identification. In Experiment 3, the RTs were longer in the change blindness relative no-change trials, which indicated that there was implicit perception.

Conclusion: The results of this study showed that there was no evidence supporting implicit detection in colour or orientation as a single or a combination of features. However, we report evidence for implicit perception during the change blindness period. Change may be implicitly perceived, but not located or identified before there is conscious detection.

Keywords: implicit detection, implicit perception, implicit localisation, implicit identification, change blindness

Introduction

In certain scenarios, even if an observer has clear vision and visual stimuli changes are large and repetitive, they will not detect a change; this can occur even when the observer can anticipate the change. This is a phenomenon called change blindness.[1,2] The phenomenon has not only been widely confirmed in humans but also in other species.[3–5] Some researchers believe that the observer has neither the representation nor implicit registration of the object.[6,7] However, other researchers have found that

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changes that are not consciously reported by the observer during the change blindness period are also processed to a certain extent.[8,9]

In a two-alternative forced-choice task, a subject is asked to make a decision about the perceived difference between two stimuli with regard to a particular stimulus parameter of interest.[10] The probability of an object with an orientation[11,12] or location change[13,14] being guessed correctly is above chance level, and the reaction times (RTs) of change blindness trials is longer than that of aware trials without a change.[11,15,16] Studies using eye tracking have found that the gaze time of a location after a change occurs was significantly longer than that of other locations.[17,18] This finding indicates that change is registered and located to a certain extent. Research using electrophysiological measures have also shown that compared to no-change trials, a change that is not consciously detected is capable of yielding a pattern of brain activity that is different from the pattern of activity resulting from a non-changing stimulus.[19–21] These findings indicate that change blindness does not necessarily imply that visual representations are fragile. However, there are also many studies that do not support such an inference and question whether implicit detection can occur.[22–26]

The initial research[27,28] that reported implicit detection used stimuli of black rectangular bars that changed orientation.[27,28] Many subsequent studies have used similar stimuli and procedures. However, these single feature stimuli may have a limitation. The change in orientation may automatically capture the observer's attention through a very faint motion transient.[29] Once attention is drawn, even a slight change in the orientation of the target will result in performance accuracy above chance level. In the visual system, there is a system that perceives changes of specific features.[30] Treisman proposed in the Feature Integration Theory that some visual features, such as colour, size and orientation, is processed in parallel in a "preattentive" front end.[31] Researchers currently working on visual search do not believe that the Feature Integration Theory model is entirely correct.[32] Static display visual search experiments have demonstrated that only orientation is pre-attentive.[33] However, there has been no evidence that complex orientation processing can occur without awareness (eg the directional adjustment effect) when processing other features.[34] Whether implicit detection can be replicated for the features of colour and size requires verification. Furthermore, it is not yet clear whether implicit detection occurs only at the level of a single feature or whether it can also occur with a combination of features.[20] The possibility of implicit detection in visual scenes is a core issue in change detection processing.[35] It would be useful to use other basic feature stimuli and combinations of feature stimuli to explore this issue.

Mitroff believes that implicit detection differs from implicit perception.[22] Implicit detection involves the implicit perception and comparison of the difference between pre-change and post-change objects; however, this comparison is not necessary for implicit perception. The evidence for implicit detection is derived from three aspects: implicit registration, localisation, and identification.[22] First, regardless of whether a change affects explicit detection, if a change affects performance, then it is implicitly registered. For example, in a change detection task, the RTs of an observer reporting whether there is change is slower for when a change is not detected than when there is no change. Secondly, if the observer does not detect a change, but guesses the location of the change at above chance, then implicit localisation has occurred. Finally, if the attribution or identification of a changed object affects subsequent processing unconsciously, then implicit identification has occurred. It should be noted that for implicit identification, there must be implicit registration first, in addition to some processing of the change itself. However, it does not require implicit localisation.[21,22] Many studies that have reported observations of implicit detection may actually be referring to implicit perception rather than implicit detection. Therefore, it is necessary to further explore which implicit processing (ie implicit detection or implicit perception) occurs during the change blindness period.

The purpose of our experiments was to explore (1) whether implicit detection can occur with basic features or a combination of features and (2) whether implicit detection or perception occurs during the change blindness period.

Overview of the Present Research

We conducted three experiments to explore the above two issues. Experiments 1 and 2 adopted a simple change detection paradigm, coupled with a speeded attribute discrimination task.[28] This combination allowed us to explore the influence that a changing object has on a subsequent attribute (orientation: vertical/horizontal; colour: red/blue) decision.[28] In regard to the relationship between the cued object and the position of the change, cues can be divided into valid or invalid. Valid cues appear where the object changes, whereas invalid cues appear where the object does not change. For the relationship between the attribute of the cued object and the attribute of the change object, the cue can be either congruent or incongruent. Congruent means that the attribute (colour or orientation) of the object that has been cued is the same as that of the change object, whereas incongruent means that the attribute (colour or orientation) of the object that has been cued is different from that of the change object (see Figure 1).

In Experiment 1, we used stimuli with different colours (or orientations) and only changed the colour (or orientation) to verify whether implicit localisation and identification can be observed for colour and orientation. If so, we would expect to observe an effect for the valid trials, where RTs to valid trials would be faster and accuracy would be higher compared with invalid trials. This is referred to as the validity effect and indicates that the position of the change object was implicitly localised.[27] If RTs were longer and error rates higher for incongruent trials compared with congruent trials, it is called a congruency effect and indicates that the attributes of the change object were implicitly identified.[12]

For the Experiment 2 stimuli, we used Gabor patches of different colours and orientations; these attributes changed simultaneously to verify whether implicit localisation and identification can be observed when features are combined. If so, we would expect to observe both a validity and a congruency effect.

In Experiment 3, we adopted a one-shot change detection paradigm, where we used different single and combination feature stimuli. Changes occurred in one or two features to verify whether implicit perception can be observed. If RTs are longer for blindness trials compared with baseline (no-change) trials, then implicit perception has occurred.

Experiment 1

Method

Thirty-one college students (14 men and 17 women; mean age 19.1 years; age range 16–22 years) volunteered to take part in Experiment 1. All participants had normal or corrected-to-normal visual acuity and had no self-reported colour blindness.

The stimuli were red (RGB: 255, 0, 0) and blue (RGB: 0, 0, 255) discs and a circle with a black rectangle (RGB: 64, 64, 64) in the centre. At a viewing distance of 60 cm, the diameter of the discs was 1° visual angle, and the size of the rectangle inside the circle was 1° × 0.2° visual angle. The rectangle had two orientations: vertical and horizontal. The stimulus display consisted of eight discs that were evenly

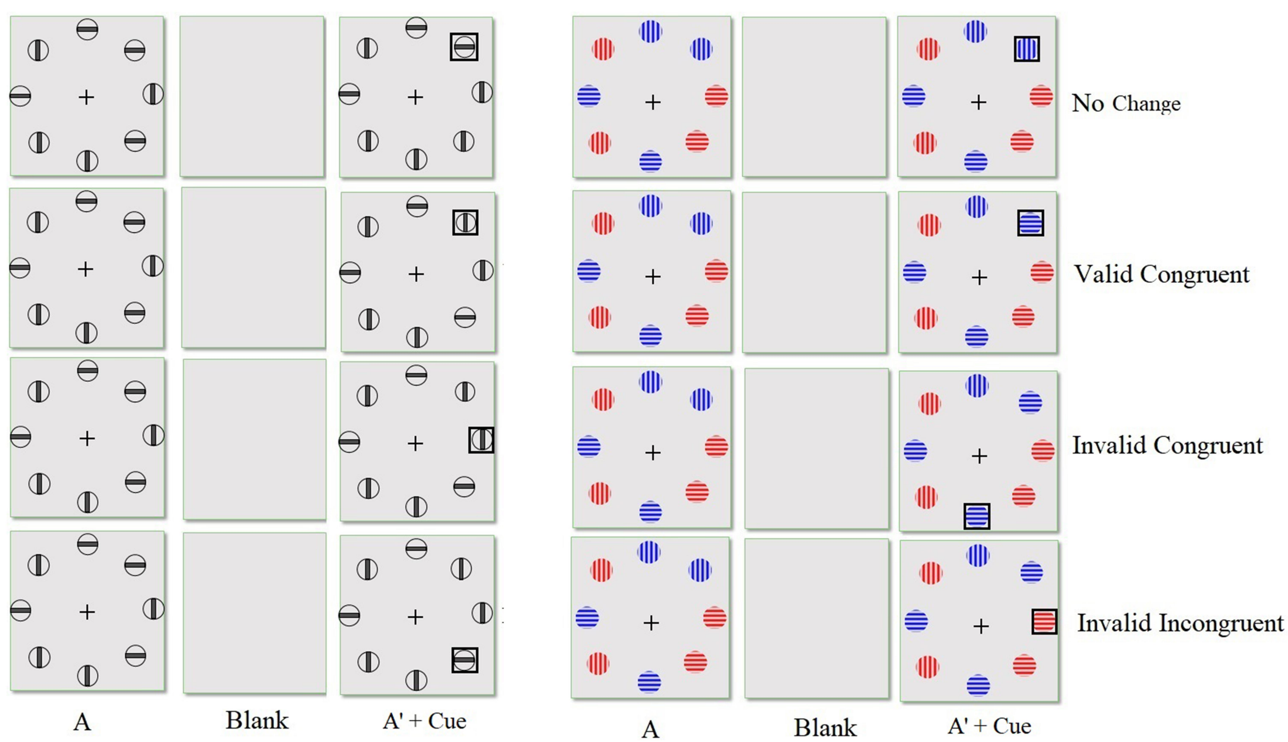

Figure 1 Example of the different cue types used in the present study. A is the pre-change display and A' is the post-change display; the cue appears in display A'. The orientation or colour of the object at 12-3 o'clock has changed. The left column represents the task of judging object orientation of the cued object. The right column represents the task of judging the object colour of the cued object.

distributed on an imaginary circle with a diameter of 10° visual angle located in the centre of the screen. The experiment was divided into two sessions. In the colour session, the stimulus display comprised eight red or blue discs, while in the orientation session, the stimulus display comprised eight circles with vertical and horizontal rectangles. The composition ratios (4/4, 5/3, 3/5) of the two attributes (red/blue, vertical/horizontal) were equal.

In each session, participants were first presented with the instructions and pressed a key to begin the experiment once they had understood the requirements (see Figure 2). A fixation point "+" with 1° visual angle was displayed in the centre of the screen for 450 ms. Subsequently, display A was presented for 450 ms, followed by display A' for 450 ms, after a 90 ms blank screen. Displays A and A' were either identical or different. Based on previous experiments,[12,22,36,37] we set our experiment so that 1/3 of trials had no change and 2/3 had change. In the change trials of the colour session, the colour of one of the objects changed from red to blue, or vice versa, and the frequency of the two changes were equal. In the change trials of the orientation session, the orientation of the rectangles of one of the objects changed from horizontal to vertical, or vice versa, and the frequency of these changes were equal. A black box appeared around one object for 40 ms as a cue. The cues of the change trials had 3 types: valid, congruent, invalid congruent and invalid incongruent, which were each presented in equal frequency. After the cue and display A' disappeared, participants were presented with the attribute judgement display. There was a brief question in the display with "red/blue?" for the colour session and "V/H?" for orientation session. The task was to judge the colour or orientation of the cued object as quickly as possible within 1200 ms by pressing the corresponding key on the keyboard: "S" for red/vertical with the left index finger and "L" for blue/horizontal with the right index finger. Correct and incorrect responses and RTs were recorded. They were instructed to respond as quickly and as accurately as possible. For half of the participants, the S key coded for red/vertical and the L key coded for blue/horizontal while the reverse mapping was used for the other half of the participants. If participants pressed a key, they were immediately presented with a change detection display, which asked the question "same or different?" Participants pressed "F" to respond with same and "J" to respond with different. Correct and incorrect responses were recorded. For half of the participants, the F key coded for same and the J key coded for different. The reverse mapping was used for the other half of the participants. If a key was not pressed, the change detection display was presented after 1200 ms. The task of the change detection display was to judge whether display A and A' were the same or different. After pressing the key, a blank screen was presented for 1000 ms before the next trial started. If after 1200 ms there was no key press, a blank screen was presented for 1000 ms and the next trial started.

Each session had 240 trials, 80 of which were no-change trials and 160 were change trials. There were 12 practice trials before the formal experiment. The order of the sessions was counterbalanced between the subjects. The experiment was written in PsychoPy 3.0[38] and presented on a screen with a resolution of 1024 × 768 pixels

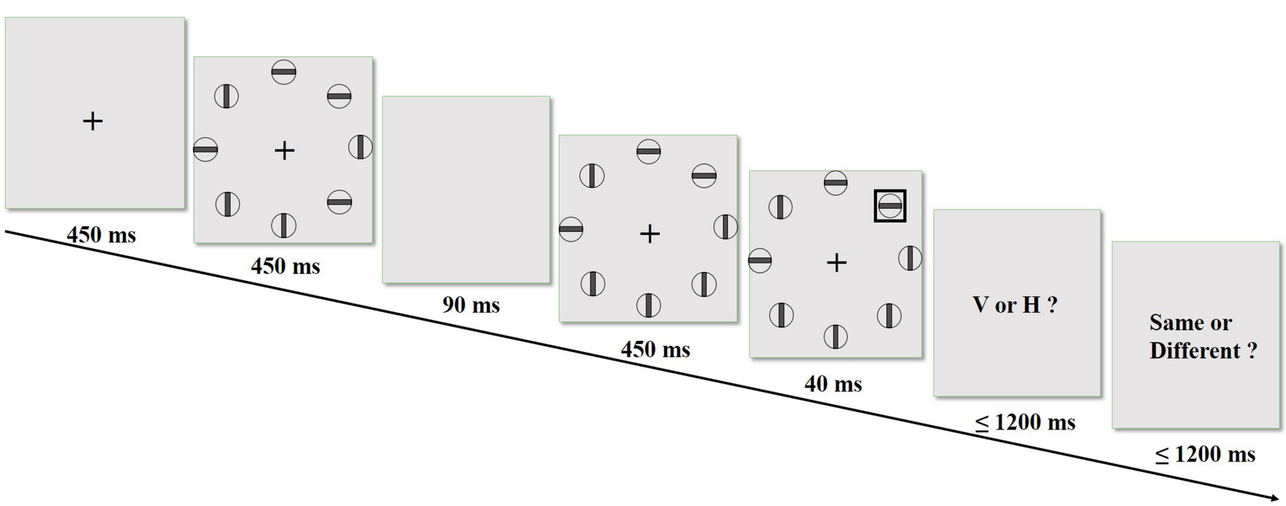

Figure 2 Illustration of the progression of a trial for Experiment 1. The orientation of the object at 3-6 o'clock has changed. The cue type is invalid incongruent.

and a refresh rate of 60 Hz. The participants were sat at a distance of 60 cm from the computer screen.

According to the theory of signal detection, if using stimulus change as the signal, trial responses can be categorised into one of the four types: hit (H; or aware trials), miss (or change blindness trials), false alarm (FA), or correct rejection (CR). We calculated the rate of these four types separately and used d_L ($d_L = \ln[H(1\text{-}FA)]/[(1\text{-}H)FA]$) to calculate the discrimination sensitivity index, as it has the fewest calculation errors.[28] Participants were excluded if their FA rate was higher or equivalent to the H rate, as this suggested poor understanding of the requirements of the change detection task.[12] The accuracy and average RTs of each subject were calculated from the data of the speeded attribute discrimination task. The calculation method of accuracy was as follows: we counted the total number of valid congruent, invalid congruent, and invalid incongruent trials in the aware and change blindness trials, respectively; we then counted the trials with correct responses for valid congruent, invalid congruent, and invalid incongruent trials in the aware and change blindness trials; finally, we divided the total number of trials by the total number of correct responses to determine the accuracy of each cue type.

Results

No participants were excluded from the analysis. Analyses were conducted on the data from all 31 participants. Figure 3 shows the accuracy and RTs for the attribute judgement task of the aware and change blindness trials.

Colour Session

The discrimination sensitivity index d_L (M = 1.88, SD = 1.13) was significantly greater than 0, t (30) = 9.29, $p <$ 0.001, d = 1.67. The average H and FA rates were 63.76% and 26.12%, respectively.

Data from invalid trials were submitted to an analysis of variance (ANOVA) with two within-subject variables: awareness of change (aware vs blindness) and congruency (congruent vs incongruent). The results showed that neither accuracy nor RTs were significantly different between the different conditions (Table 1).

Data from congruent trials were submitted to an ANOVA with two within-subject variables: awareness of change (aware vs blindness) and validity (valid vs invalid). The results showed that neither accuracy nor RTs were significantly different between the different conditions (Table 2).

Orientation Session

The discrimination sensitivity index d_L (M = 1.08, SD = 1.06) was significantly greater than 0, t (30) = 5.78, $p <$ 0.001, d = 1.05. The average H and FA rates were 49.89% and 28.37%, respectively.

Data from invalid trials were submitted to an ANOVA with two within-subject variables: awareness of change (aware vs blindness) and congruency (congruent vs incongruent). The results showed that the RTs of aware trials (709.62 ± 96.74 ms) were significantly longer than that of change blindness trials (669.68 ± 85.71 ms) (Table 3).

Data from congruent trials were submitted to an ANOVA with two within-subject variables: awareness of

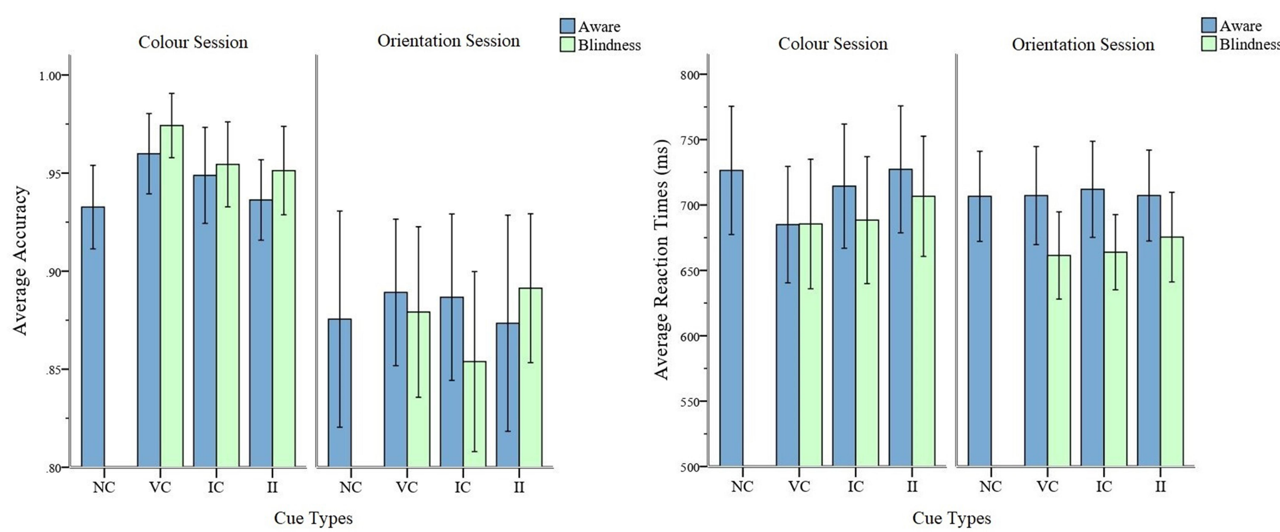

Figure 3 The accuracy and RTs for the attribute judgement task in Experiment 1. Error bars represent 95% confidence intervals.
Abbreviations: NC, no-change; VC, valid change; IC, invalid congruent; II, invalid incongruent.

Table 1 The Results of the ANOVA of the Invalid Trials from the Colour Session for Experiment 1

	Accuracy			Reaction Times		
	$F(1, 120)$	p	η_p^2	$F(1, 120)$	p	η_p^2
Awareness	0.89	0.35	0.01	1.00	0.32	0.01
Awareness×Congruency	0.18	0.67	0.01	0.01	0.91	0.01
Congruency	0.52	0.41	0.01	0.44	0.51	0.01

Table 2 The Results of the ANOVA of the Congruent Trials from the Colour Session for Experiment 1

	Accuracy			Reaction Times		
	$F(1, 120)$	p	η_p^2	$F(1, 120)$	p	η_p^2
Awareness	0.21	0.65	0.01	0.18	0.66	0.01
Awareness×Congruency	0.24	0.63	0.01	0.18	0.68	0.01
Congruency	1.20	0.28	0.01	1.45	0.23	0.01

Table 3 The Results of the ANOVA of the Invalid Trials from the Orientation Session for Experiment 1

	Accuracy			Reaction Times		
	$F(1, 120)$	p	η_p^2	$F(1, 120)$	p	η_p^2
Awareness	0.11	0.74	0.01	5.84	0.02	0.05
Awareness×Congruency	1.28	0.26	0.01	0.24	0.62	0.01
Congruency	0.29	0.59	0.01	0.04	0.84	0.01

change (aware vs blindness) and validity (valid vs invalid). The results showed that the RTs of aware trials (709.60 ± 100.43 ms) were significantly longer than that of change blindness trials (662.65 ± 84.20 ms) (Table 4).

Discussion of Experiment 1

The purpose of Experiment 1 was to verify whether implicit localisation and identification can be replicated for the features of orientation and colour. In previous studies,[12,28] the orientation stimuli consisted of black rectangle bars. We added a circle around the bars to reduce the potential effects of motion transients and tested whether we could replicate previous evidence of implicit detection. In the colour and orientation sessions, the discrimination sensitivity index d_L was significantly greater than 0, which indicated that the subjects could distinguish between change and no-change trials. In the colour session, differences in accuracy and RT of the invalid and congruent conditions were not significant. In the orientation session, the RTs of the aware trials were significantly longer than that of the change blindness trials, regardless of whether they were from the invalid or congruent conditions. Experiment 1 did not yield evidence for implicit localisation or identification.

Change detection includes an accumulation of implicit processes over time. There is a threshold that determines whether the change signal is detected explicitly or implicitly. If the accumulated change signal is higher than this threshold, there will be explicit detection, where if it is lower, then implicit detection will occur.[25] For a given

Table 4 The Results of the ANOVA of Congruent Trials from the Orientation Session for Experiment 1

	Accuracy			Reaction Times		
	$F(1, 120)$	p	η_p^2	$F(1, 120)$	p	η_p^2
Awareness	0.97	0.33	0.01	7.83	0.006	0.06
Awareness×Congruency	0.25	0.62	0.01	0.01	0.95	0.01
Congruency	0.39	0.54	0.01	0.05	0.83	0.01

trial, the greater the change between the pre- and post-change scenes, the higher the accumulated change signal, and the higher the likelihood for implicit detection.[39] We conducted Experiment 2 using combination feature stimuli to test whether implicit localisation and identification occurs when there is a higher change signal.

Experiment 2

Method

Thirty-one college students (14 men and 17 women; mean age 19.1 years; age range 16–22 years) volunteered to take part in Experiment 2. All participants had normal or corrected-to-normal visual acuity and had no self-reported colour blindness.

The stimuli were Gabor patches with different colours and orientations, which were generated by the Online Gabor-patch generator (https://www.cogsci.nl/pages/gabor-generator) with the following parameters: orientation, 0°/90°; envelope, circular (sharp edge); frequency, 0.04; phase, 0. The colours and RGB values were as follows: red (255, 0, 0) and blue (0, 0, 255). Stimuli were presented at a viewing distance of 60 cm and had a diameter of 1° visual angle. The experimental design and procedure were the same as Experiment 1 except that the object changed in colour and orientation simultaneously. During the attribute judgement task, subjects were required to only judge the colour of the cued object in the colour session and only the orientation in the orientation session.

Results

No participants were excluded from the analysis. Analyses were conducted on the data from all 31 participants. Figure 4 shows the accuracy and RTs for the attribute judgement task of the aware and change blindness trials.

Colour Session

The discrimination sensitivity index d_L (M = 2.25, SD = 1.25) was significantly greater than 0, t (30) = 10.04, $p <$ 0.001, d = 1.81. The average H and FA rates were 74.74% and 34.77%, respectively.

Accuracy and RT data from invalid trials were submitted to an ANOVA with two within-subject variables: awareness of change (aware vs blindness) and congruency (congruent vs incongruent). The results showed that there was no significant difference between the different conditions in either accuracy or RTs (Table 5).

Data from congruent trials were submitted to an ANOVA with two within-subject variables: awareness of change (aware vs blindness) and validity (valid vs invalid). The results showed that there was no significant difference between the different conditions in either accuracy or RTs (Table 6).

Orientation Session

The discrimination sensitivity index d_L (M = 1.50, SD = 0.92) was significantly greater than 0, t (30) = 9.12, $p <$ 0.001, d = 1.64. The average H and FA rates were 59.20% and 30.71%, respectively.

Data from invalid trials were submitted to an ANOVA with two within-subject variables: awareness of change (aware vs

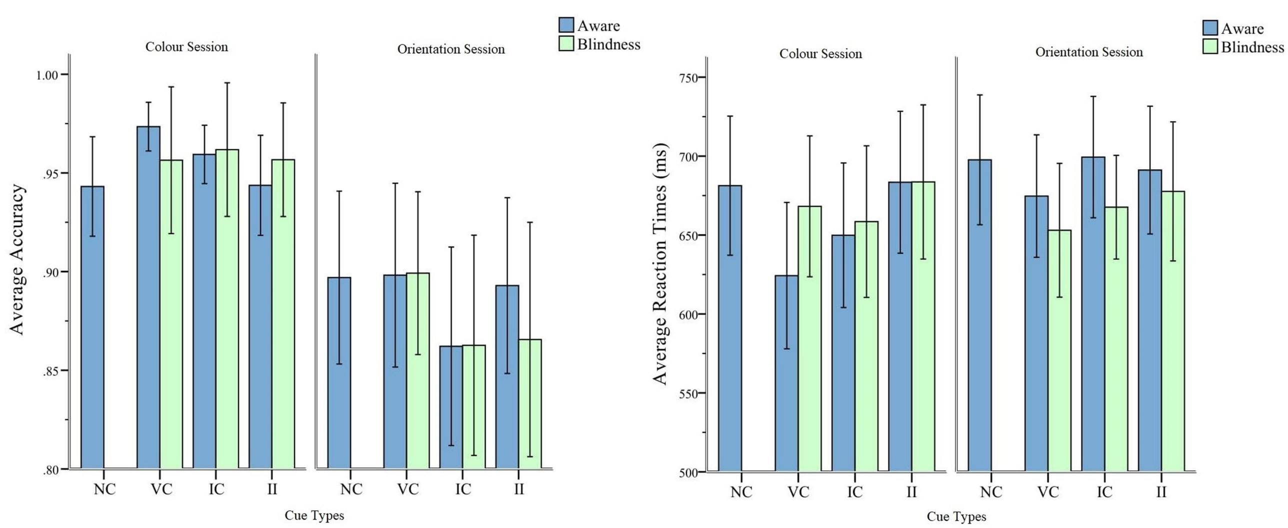

Figure 4 The accuracy and RTs for the attribute judgement task in Experiment 2. Error bars represent 95% confidence intervals.
Abbreviations: NC, no-change; VC, valid; IC, invalid congruent; II, invalid incongruent.

Table 5 The Results of the ANOVA of the Invalid Trials from the Colour Session for Experiment 2

	Accuracy			Reaction Times		
	$F(1, 120)$	p	η_p^2	$F(1, 120)$	p	η_p^2
Awareness	0.49	0.49	0.01	0.03	0.87	0.01
Awareness×Congruency	0.09	0.768	0.01	0.02	0.88	0.01
Congruency	0.82	0.37	0.01	1.82	0.18	0.02

Table 6 The Results of the ANOVA of the Congruent Trials from the Colour Session for Experiment 2

	Accuracy			Reaction Times		
	$F(1, 120)$	p	η_p^2	$F(1, 120)$	p	η_p^2
Awareness	0.31	0.58	0.01	1.35	0.25	0.01
Awareness×Congruency	0.54	0.46	0.01	0.61	0.44	0.01
Congruency	0.11	0.74	0.01	0.12	0.73	0.01

Table 7 The Results of the ANOVA of the Invalid Trials from the Orientation Session for Experiment 2

	Accuracy			Reaction Times		
	$F(1, 120)$	p	η_p^2	$F(1, 120)$	p	η_p^2
Awareness	0.32	0.57	0.01	1.19	0.28	0.01
Awareness×Congruency	0.26	0.61	0.01	0.15	0.70	0.01
Congruency	0.29	0.59	0.01	0.02	0.90	0.01

blindness) and congruency (congruent vs incongruent). The results showed that neither accuracy nor RT were significantly different between the different conditions (Table 7).

Data from congruent trials were submitted to an ANOVA with two within-subject variables: awareness of change (aware vs blindness) and validity (valid vs invalid). The results show that neither accuracy nor RT were significantly different between the different conditions (Table 8).

Discussion of Experiment 2

The purpose of Experiment 2 was to verify whether implicit localisation and identification can be observed at the combined feature level. In the colour and orientation sessions, the discrimination sensitivity index d_L was significantly greater than 0, indicating that the subjects could distinguish between the change and no-change trials. In both the colour and the orientation sessions, the accuracy and RT of the valid and congruent conditions were not significantly different. We did not find evidence of implicit localisation or identification in Experiment 2.

Experiment 3

Method

Thirty-one college students (16 men and 15 women; mean age 19.3 years; age range 17–23 years) volunteered to take part in Experiment 3. All participants had normal or corrected-to-normal visual acuity and had no self-reported colour blindness.

Table 8 The Results of the ANOVA of the Congruent Trials from the Orientation Session for Experiment 2

	Accuracy			Reaction Times		
	$F(1, 120)$	p	η_p^2	$F(1, 120)$	p	η_p^2
Awareness	0.01	0.91	0.01	1.58	0.21	0.01
Awareness×Congruency	0.01	0.96	0.01	0.06	0.81	0.01
Congruency	2.04	0.16	0.02	1.17	0.28	0.01

The experiment was divided into four sessions: colour, size, orientation, and combination features. The colour session stimuli were red (RGB: 255, 0, 0), orange (RGB: 255, 128, 0), green (RGB: 0, 255, 0), and blue (RGB: 0, 0, 255) discs. The diameter of the disc was 1° visual angle, which were presented at a viewing distance of 60 cm. The size session stimuli were black (RGB: 64, 64, 64) discs. The diameter of the large disc was 1.25° visual angle, that of the middle was 1° visual angle, and that of the small was 0.75° visual angle. In the orientation session, the stimulus was a circle with a black rectangle (RGB: 64, 64, 64) in the middle. The diameter of the circle was 1° visual angle, and the size of the rectangle was 1° × 0.2° visual angle, tilted at 0°, 45°, 90°, and 135° in the vertical direction. The combination feature stimuli were Gabor patches of different colours, sizes, and orientations. The colour and size parameters of the Gabor patches corresponded to those in the colour and size sessions. The orientation of the Gabor patches was either vertical or horizontal. The stimulus display consisted of nine stimuli distributions on an imaginary 3 × 3 grid, which had a size of 9° × 9° visual angle.

The instructions were presented at the beginning of each session. Once the participants understood the experimental requirements, they pressed a key to start. The fixation point "+" was 1° visual angle, which was displayed in the centre of the screen for 300 ms. Display A was presented for 500 ms, followed by display A' for 500 ms following a 100 ms blank screen. Displays A and A' were either identical or different. In the colour, size, and orientation sessions, one object changed in colour, size, or orientation, respectively. In the combination feature session, two of the three features (ie colour, size, or orientation) of one object changed simultaneously; the change trials of different combinations of features were equal. After display A' disappeared, the response prompt display was presented with question asking "same or different?" Subjects were required to report whether display A and A' were the same or different, as quickly as possible. For same, they were instructed to press "F", and for different they pressed "J" on the keyboard. Correct and incorrect responses were recorded. For half of the participants, the F key coded for same and J for different. The reverse mapping was used for the other half of the participants. After pressing the corresponding key, a blank screen was presented for 1000 ms before the next trial began. If no key was pressed for 1200 ms, a blank screen was presented for 1000 ms then the next trial started. The pressed key and RT were recorded for each trial. Each session had 240 trials, of which 80 were no-change trials and 160 were change trials. There were 12 practice trials before the formal experiment. The order of the sessions was counterbalanced between the subjects.

The experiment was written in E-Prime 2.0 and presented on a screen with a resolution of 1024 × 768 pixels and a refresh rate of 60 Hz. The participants were sat at a distance of 60 cm from the computer screen.

According to the signal detection theory, we calculated the FA rate, H rate, and d_L. Participants whose FA ≥ H were excluded. Then, a paired-samples *t*-test was performed for the RTs of the change blindness and baseline trials. For the change blindness trials, the stimulus exhibited a change but participants reported "same". For the baseline trials, the stimulus exhibited no changed and the participants reported "same".

Results

Six participants were excluded from the analysis. Analyses were conducted on the data from remaining 25 participants (11 men and 14 women; mean age 19.0 years; age range 17–23 years; Table 9).

In the colour session, discrimination sensitivity index d_L (M = 1.79, SD = 0.94) was significantly greater than 0, t (24) = 9.49, $p < 0.001$, $d = 1.89$. The average H and FA rates were 48.95% and 17.00%, respectively. The RTs of the change blindness trials were significantly longer than that of the baseline trials (t (24) = 4.34, $p < 0.001$, $d = 0.87$; see Figure 5).

In the size session, the discrimination sensitivity index d_L (M = 1.34, SD = 0.75) was significantly greater than 0, t (24) = 8.93, $p < 0.001$, $d = 1.79$. The average H and FA rates were 42.35% and 20.49%, respectively. The RTs of the change blindness trials were significantly longer than that of the baseline trials (t (24) = 2.68, $p = 0.013$, $d = 0.54$; see Figure 5).

In the orientation session, the discrimination sensitivity index d_L (M = 1.18, SD = 0.81) was significantly greater than 0, t (24) = 7.32, $p < 0.001$, $d = 1.46$. The average H and FA rates were 46.45% and 26.72%, respectively. The RTs of the change blindness trials were significantly longer than that of the baseline trials (t (24) = 2.04, p = 0.053, $d = 0.41$; see Figure 5).

In the combination feature session, the discrimination sensitivity index d_L (M = 2.33, SD = 0.68) was significantly greater than 0, t (24) = 17.19, $p < 0.001$, $d = 3.43$. The average H and FA rates were 59.08% and 16.15%, respectively. The RTs of the change blindness trials were

Table 9 The Average d_L, H and FA Rates, and Reaction Times (in ms) for Experiment 3

	d_L	H	FA	Baseline RTs	Blindness RTs
Colour	1.79(0.94)	0.49	0.17	336.68(103.91)	364.59(106.10)
Size	1.34(0.75)	0.42	0.20	337.13(103.59)	352.11(98.84)
Orientation	1.18(0.81)	0.46	0.27	325.10(101.54)	340.89(99.74)
Combination	2.33(0.68)	0.59	0.16	298.02(91.36)	314.44(86.80)

Note: Standard deviations appear in parentheses.

significantly longer than that of the baseline trials (t (24) = 2.48, p = 0.021, d = 0.50; see Figure 5).

Discussion of Experiment 3

Because Experiment 1 and Experiment 2 did no show significant differences in accuracy rate or RTs for the invalid or congruent conditions, there was no evidence of implicit localisation or identification. Therefore, Experiment 3 was conducted to verify whether implicit perception can be observed on different basic features. Implicit perception does not have to include implicit localisation or implicit identification. The discrimination sensitivity index d_L of each session was significantly greater than 0, which indicated that the subjects could distinguish between the change and no-change trials. The RTs for the change blindness trials of each session were significantly longer than that of the baseline trials. According to the definition of implicit perception,[40] implicit perception refers to when a stimulus is not consciously attended to by an individual but has an impact on the individual's behaviour. In other words, the individual unconsciously processes and responds to external stimuli. The result meets this definition and indicates that implicit perception has occurred.

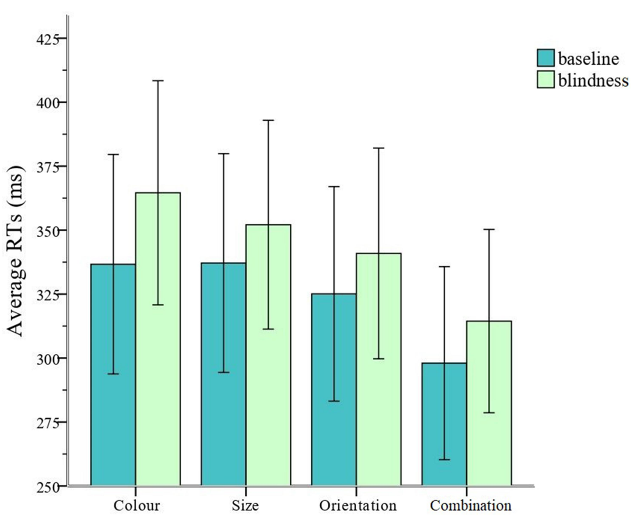

Figure 5 Average reaction times (in ms) of baseline trials and change blindness trials for Experiment 3. Error bars represent 95 confidence interval.

General Discussion

There is a difference between implicit detection and perception.[22] Many studies have claimed to have found evidence of implicit detection during change blindness, though the two are not clearly distinguished. The purpose of this research was to use basic visual features to explore this issue.

If implicit detection exists, then change representation can happen without awareness. Detection of changing positions should be faster and more accurate than detection in other positions;[27] a subject's reaction to valid trials would be faster than that of invalid trials and the accuracy rate would be higher. This is referred to as the validity effect. The lack of validity effects may indicate some form of automatic, pre-attention change representation,[27] where the processing of some visual features and objects does not require awareness.[41,42] If an observer responds slower in incongruent compared with congruent trials and the error rate is higher, this is called the congruency effect. This indicates that the attributes of the change object were implicitly represented.[12]

Response biases indexed by implicit and explicit measures are assumed to respectively reflect automatically or deliberately retrieved associations;[43] the difference in performance infers implicit perception.[44] Therefore, the validity and congruency effects are important because they show that in the absence of awareness, the visual system not only maintains the fact that a change has occurred but also locates and identifies the change.[11]

In Experiments 1 and 2, the RTs of the orientation session aware trials were significantly longer than that of the change blindness trials. It may be that the change of orientation produced a weak motion transient. This transient would capture the focal attention[29] and increase the time for choice and judgement when subject are aware, resulting in longer RTs. One interpretation could be a form of strategic slowing,[28] where subjects consciously search an internal representation of the pre-change scene and compare with the post-change scene. An alternative interpretation could be a reflection of an attentional blink or psychological refractory period. That is, additional processing or response preparation associated with consciously detecting the change is likely to interfere with the orientation response.[28] All in all, the results did not provide evidence to support validity or congruency effects, which suggests that no implicit localisation or identification occurred.

In Experiment 3, the RTs of the change blindness trials (ie when the stimulus exhibits a change but participants reported "same") were longer than that of the baseline trials (ie stimulus exhibits no change and participants report "same"). Some researchers suggest that observers might respond with varying degrees of confidence depending on their criterion.[25] For example, a participant may feel less confident in change blindness trials, which would result in slower RTs, which are then mistakenly interpreted as evidence for implicit perception. One method to test this hypothesis is to add a subjective confidence rating to the change detection response.[12,45] Such a procedure requiring participants to rate how self-confident they were in their responses through a graded scale, from guess to certain. Results have shown that this prolongation was not related with subjects' confidence in judgement.

Studies using electrophysiological methods to investigate differences in event-related potentials (ERPs) between change blindness trials and baseline trials have shown differences in time courses and topographic distributions.[19–21,46] These results support implicit perception more consistently. In particular, Scrivener used a similar paradigm and found that confidence ratings were not directly correlated with single-trial ERP amplitudes.[21]

In a change detection study, Williams performed correlation analyses between each subject's RT for change blindness and baseline trials, discrimination sensitivity, and response bias.[39] Results showed that the difference in RTs of each subject was not highly correlated with sensitivity or bias. The phenomenon where RTs of change blindness trials are longer than that of the baseline trials cannot be attributed to a particular subject performing particularly well in a change detection task or a subject's bias toward a response (ie same or different).[39]

In summary, the occurrence of implicit perception is the best explanation for the RTs of the change blindness trials being longer than that of the baseline trials.[11]

Most feature integration theories treat early visual perception as a multi-stage process.[47] At the first stage, visual input is decomposed into basic features, such as colour and orientation. Treisman believed that a few features could be processed in parallel in a "preattentive" front end.[31] Preattentive registration of features can allow for the detection of a feature's presence, but not for its localisation or identification of a unified object.[48] At the next stage, these basic features and their locations are bound together to form coherent object representations, availing these objects to conscious perception.[48]

Therefore, the change of an object's feature may be registered in the absence of consciousness or feature binding, and may even be unconsciously perceived. However, it cannot be localised or identified before there is conscious detection.

Conclusion

In conclusion, we did not observe a validity or congruency effect as evidence for implicit localisation or identification, respectively. In other words, we found no evidence for implicit detection in colour or orientation as a single or combination of features. However, we found evidence for implicit perception during the change blindness period. One must be cautious when reporting implicit detection because implicit detection differs from implicit perception. The former includes implicit registration, localisation, identification, and comparison of an object. Implicit comparison is not necessary for implicit perception, and there should not be any identification or localisation of the object. Implicit perception alone is not sufficient to demonstrate implicit detection. The change of an object's feature may be registered in the absence of focal attention and feature binding and may even be consciously perceived. However, the change cannot be located or identified before they are explicitly detected.

Ethical Approval and Consent to Participate

This study was approved by the Ethical Committee of Guangxi University for Nationalities and complied with the Declaration of Helsinki. The Ethical Committee approved the study for participants under 18 years to provide their own consent. All participants provided written informed consent to participate in the study after having received a description of the aims. Confidentiality and anonymity were ensured. Participants were given the right to withdraw from the study at any time and their responses would not be included in the study.

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