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RECOGNITION WITHOUT AWARENESS IN A PATIENT WITH SIMULTANAGNOSIA

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Abstract

We report a psychophysiological study of “recognition without awareness” in patient 2354, who had severe but circumscribed atrophy in the occipitoparietal region bilaterally (caused by visual-variant Alzheimer’s disease, documented by structural and functional neuroimaging) and an accompanying Balint syndrome that prevented her from recognizing the emotional valence of many highly charged negative visual scenes (e.g., a burned body). Despite this lack of overt recognition, patient 2354 nonetheless generated large amplitude skin conductance responses to highly charged negative pictures, demonstrating the same kind of recognition without awareness that has been reported previously in patients with bilateral occipitotemporal dysfunction and prosopagnosia (e.g., Tranel & Damasio, 1985). Our case complements both previous evidence of covert, nonconscious recognition in patients with prosopagnosia, and previous behavioral studies of patients with Balint syndrome that have shown evidence of “preattentive” visual processing. The findings add to the small but important set of empirical observations regarding nonconscious visual processing in neurological patients, and indicate that recognition without awareness can occur in the setting of dorsal visual stream dysfunction and Balint syndrome. The findings in our patient suggest that she has patent pathways from higher order visual cortices to autonomic effectors in amygdala or hypothalamus, even though the results of such information processing are not made available to conscious awareness.

INTRODUCTION

Balint syndrome is an acquired disorder affecting the ability to perceive the visual field as a whole, most commonly following damage to the occipitoparietal region, bilaterally. The syndrome involves three components: (1) simultanagnosia (also known as visual disorientation); (2) ocular apraxia (also known as psychic gaze paralysis); and (3) optic ataxia. The key component in the syndrome, however, is simultanagnosia (Husain & Stein, 1988; Rafal, 2001).

Simultanagnosia refers to the subjective inability to attend to more than a very limited sector of the visual field at any given moment. Patients report that they can see clearly in only a small part of the field, the rest being “out of focus” and in a sort of “fog.” Further, the sector of clear vision is unstable, and may shift without warning in any direction, so that patients experience a literal “jumping about” of their visual perception (Rizzo, 1993). Patients with

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simultanagnosia can perceive color and shape normally, provided the objects are appreciated within a clear sector of the visual field.

An example of simultanagnosia is illustrated with the picture in Figure 1. Here, the patient with Balint syndrome, who is the subject of the present case study, was presented with a simple line drawing of a wreath (item taken from the Boston Naming Test; Kaplan, Goodglass, & Weintraub, 2001), and asked to respond to the question, “What is this?” The patient responded “bow,” not apprehending and appreciating that the entire drawing is of a “wreath,” indicating that her sector of vision at that moment did not include the upper portion of the line drawing.

As noted, Balint syndrome is associated with bilateral occipitoparietal lesions, although unilateral lesions can also produce the syndrome, especially when lateralized to the right (Damasio, Tranel, & Rizzo, 2000). Functionally, the occipitoparietal pathway can be considered as part of the dorsal visual stream in humans (the so-called “where” system), and it is especially involved in spatial analysis. Damage to this system has been linked to simultanagnosia (see Rafal, 2001, for a review). The lesions are commonly caused by infarcts in the border zone (watershed) between the anterior and posterior cerebral artery territories. Balint syndrome can also be caused by bilateral metastases in the occipitoparietal region. More recently, Balint syndrome has been associated with degenerative disease, such as degeneration of the posterior cortices of the brain, sometimes referred to as visual variant of Alzheimer’s disease (VVAD), progressive visuospatial dysfunction (Mendez, Ghajranian, & Perryman, 2002; Mesulam, 2001), or posterior cortical atrophy (Benson, Davis, & Snyder, 1988; Victoroff, Ross, Benson, Verity, & Vinters, 1994). There is also a single report of Balint syndrome in a patient with corticobasal ganglionic degeneration (Mendez, 2000).

VVAD is an atypical presentation of AD, in which the initial complaints involve visual problems, difficulty reading, and topographical disorientation. Preservation of personality, behavior, judgment, and insight has been demonstrated in such patients, and neuropsychological testing typically yields normal or near-normal performances on tests of memory and executive functions. Patients tend to present to an optometrist or ophthalmologist for initial evaluation, although testing is usually unremarkable. Neuropathologically, there tends to be an unusual posterior predominance (i.e., occipital and parietal brain regions) of neuritic plaques and neurofibrillary tangles, the hallmark signatures of AD pathology. Balint-type symptoms—simultanagnosia, ocular apraxia, optic ataxia—may also manifest in VVAD patients (Graff-Radford et al., 1993; Mendez & Chierri, 1998). This presentation stands in contrast with the typical presentation of AD, which is hallmarked by memory impairment and mesial temporal lobe pathology and rarely includes prominent visuospatial defects (at least in the early stages). In the visual variant of AD, there appears to be disruption of specific visual association pathways that are normally spared in AD.

We had the opportunity to investigate in detail a patient of ours who presented with VVAD and Balint syndrome. What made this patient especially intriguing, and of relevance to the topic of how psychophysiological parameters can be used to index the interactions of central and peripheral nervous system phenomena, is that the patient manifested a type of “recognition without awareness” that has rarely been reported in connection with Balint syndrome and dorsal stream visual dysfunction. In fact, nearly all of the published reports of recognition without awareness in neurological patients with visual disorders have been in connection with various types of object and/or face agnosia, in the setting of ventral stream visual dysfunction. Our unusual case thus afforded an opportunity to explore the phenomenon of recognition without awareness in more depth, and to determine whether such a phenomenon could indeed manifest in the setting of dorsal stream visual dysfunction. The findings from our patient turned out to be especially intriguing, making it worthwhile to contribute these data to the small but important set of empirical observations regarding recognition without awareness in

neurological patients. Before reporting the case, we summarize briefly the relevant background on recognition without awareness, and related aspects of “nonconscious recognition.”

It had been demonstrated in early psychophysiological studies that normal, healthy participants are able to produce evidence of detection and recognition of stimuli that had been degraded or camouflaged so as to escape conscious awareness (Adams, 1957; Corteen & Wood, 1972; Lazarus & McCleary, 1951; Reiser & Block, 1965; Rousey & Holzman, 1967). The most convincing verification of this phenomenon came from psychophysiological data, such as the skin conductance response (SCR). In the mid 1980's, our laboratory and others (Bauer, 1984; Bauer & Verfaellie, 1988; Tranel & Damasio, 1985; Tranel & Damasio, 1988) used the rationale from this line of work to study nonconscious recognition in neurological patients.

Nonconscious recognition has been demonstrated in neurological patients with the condition known as prosopagnosia, in which the ability to recognize familiar faces (e.g., family members, close friends, and even their own face) is severely impaired, despite normal visual perceptual abilities (i.e., the affected patients can “see” normally). Prosopagnosia is caused by bilateral occipitotemporal lesions, thus implicating the ventral stream “what” visual pathway. Tranel and Damasio (1985, 1988) used a psychophysiological index (SCRs) to explore whether prosopagnosic patients, despite their striking inability to recognize familiar faces consciously, might produce psychophysiological evidence that they can discriminate well-known faces from faces of strangers. Skin conductance was recorded while the patients viewed familiar and unfamiliar face stimuli (i.e., family members, themselves, and famous persons, mixed in random order with faces the patients had never seen before). The patients produced significantly larger-amplitude SCRs to familiar faces, compared to unfamiliar ones, indicating evidence of nonconscious discrimination of facial stimuli they could not otherwise recognize, and for which even a remote sense of familiarity was lacking. Such a nonconscious face recognition phenomenon has even been reported in a 5-year-old boy with a developmental form of prosopagnosia (Jones & Tranel, 2001). Other experimental paradigms have also yielded evidence of nonconscious or “covert” face recognition in prosopagnosic patients (Bauer, 1984; Bauer & Verfaellie, 1988; de Haan et al., 1987; Farah & Feinberg, 1997; Rizzo et al., 1987; Viggiano, 1996).

As noted, there are a few reports of “implicit” visual processing in the setting of dorsal visual stream dysfunction (Coslett & Saffran, 1991; Coslett et al., 1995; Filoteo et al., 2002; Stark et al., 1997; Wojciulik & Kanwisher, 1998). The most recent of these was a case study reported by Filoteo and colleagues (2002). Their patient, M.H., was a 66-year-old man with posterior cortical atrophy and Balint syndrome, whose condition was confirmed by an MRI of the brain, a visual evoked potential study, and neuropsychological data. M.H. was administered two global-local tasks, one with *congruent* stimuli (e.g., a large ‘H’ made up of smaller ‘H’s’) and one with *incongruent* stimuli (e.g., a large ‘H’ made up of smaller ‘S’s’). Results from several tasks indicated that M.H. was wholly unable to consciously identify global forms. However, he was able to process local targets, and critically, was better at this in the congruent condition than in the incongruent condition. Thus, M.H. demonstrated the interference effect typically seen in normal individuals, which was interpreted as a form of implicit knowledge processing (Filoteo et al., 2002). The few other cases in the literature focused on similar types of behavioral effects, and none of them used a primary psychophysiological index as a dependent measure (we return to this literature in the Discussion).

In the current report, we present a case of nonconscious visual recognition, indexed by psychophysiology, in a patient with dorsal visual stream dysfunction. The subject of the report is patient 2354, who at the time of our study was a middle-aged woman with VVAD. Patient 2354 had Balint syndrome (including simultanagnosia), and we used the methodology of our earlier work in prosopagnosia to investigate the extent to which patient 2354 might be able to

generate psychophysiological evidence (based on SCRs) that her brain was “recognizing” the affective valence of stimuli that she could not consciously apprehend and report. We offer the case in the spirit of adding to the empirical base that has supported the phenomenon of recognition without awareness, a base that is not large and that can benefit from broader empirical footing.

METHODS

Participant

At the time of the studies reported here, patient 2354 was a 50-year-old fully right-handed, married, Caucasian female, from a small Iowa town. She completed 12 years of formal education, and denied academic problems. She presented to our laboratory with a two-year history of progressive visual difficulties, mild depression, and a circumscribed medical history of hysterectomy and well-controlled hypertension. Her visual problems led to her discontinuing her employment as a grocery store worker (e.g., “The numbers on the adding machine were gone.”) and, later, she was dismissed from a job as a factory line worker also because of her visual problems. Her husband confirmed these reports. There is no notable family medical history.

On exam, patient 2354 demonstrated all aspects of Balint syndrome (simultanagnosia, ocular apraxia, and optic ataxia). She displayed especially prominent simultanagnosia, as evidenced in her daily life (e.g., inability to use adding machine and telephone, inability to tell time), upon clinical observation (e.g., when asked to describe objects within the examination room), and during formal neuropsychological testing (e.g., multiple errors on visual naming tests and in her description of the Cookie Theft drawing). In all of these examples, her responses were typical of patients with simultanagnosia—she would report a small sector of what she was looking at, but fail to “see” the entire scene. The sector of clear vision was unstable and unpredictable, and would jump around haphazardly from one part of her visual field to the other. Patient 2354 displayed moderately severe optic ataxia, whereby she was inaccurate in her visually-guided pointing and reaching behavior, often missing entirely or reaching beyond the target. For example, when asked to point to the examiner’s fingertip with her fingertip, she would slowly approach the target, and then grasp the examiner’s hand with her hand and “feel” her way to the end of the examiner’s fingertip. With regard to ocular apraxia, we found her deficit to be relatively mild, best characterized by problems redirecting her gaze from one fixated object to another. This was manifest especially when a new object was introduced into the periphery of her visual panorama—e.g., when someone new entered the room, she would have difficulty directing her gaze to fixate the new person. Neuro-ophthalmological examination demonstrated normal visual fields and normal visual acuity.

Neuropsychological Assessment—Patient 2354 underwent two neuropsychological evaluations, approximately six months apart. These data are presented in Table 1. During both evaluations, patient 2354 was oriented to person, place, and time. Her speech was fluent, well-articulated, and non-paraphasic, and her comprehension of spoken language was fully intact. However, mild word-finding problems were evident. Behaviorally, patient 2354 was observed to be significantly anxious on both testing occasions, which may have served to reduce her neuropsychological performances, at least to some extent, and especially on memory and concentration tests. Self-reported mood was mildly depressed, secondary to her neurological condition and subsequent loss of employment and independent activities of daily living. No personality abnormalities were observed nor reported by patient or family. Patient 2354’s insight into her deficits was very much intact, and she was quite accurate in her description of progressive difficulties over the last several years. Finally, her social graces appeared intact.

On selected subtests of intellectual functioning, patient 2354's performances ranged from Severely Impaired to Average, and several of the "hold" tests—i.e., tasks that are thought to be relatively resistant to neurological dysfunction—suggested that she likely functioned in the low-end to middle-range of Average premorbidly. Administration of standard academic achievement measures was precluded by the patient's visual difficulties.

Mild anterograde memory problems were suggested by patient 2354's performances on a verbal list-learning and memory test, as her scores were approximately one standard deviation below expectations. Mild attentional difficulties, also on the order of one standard deviation below expectations, were observed. As noted, her anxiety likely contributed to some of these low scores. Language abilities ranged from defective to intact: phonemic verbal fluency was significantly below expectations, falling in the defective range, while responsive naming was intact. (Performance on a visual confrontation naming test was impaired, but this was considered to be secondary to her visual impairments.) Tests of executive functioning were discontinued secondary to patient 2354's visual difficulties; however, behavioral observations indicated that her executive abilities were probably at a level consistent with her performances in other cognitive domains, such as memory, attention, and language. Severe impairments were also evident in visuoconstruction (e.g., clock drawing) and visuoperception. As is often the case in Balint syndrome (Damasio et al., 2000), praxis and color naming were normal.

The neuropsychological findings indicate that patient 2354 has an atypical dementia, with marked simultanagnosia, deficits in visuoperception and visuoconstruction, optic ataxia, and mild ocular apraxia. Very mild progressive decline was suggested based on serial evaluations, six months apart. Taken together, the striking feature in this case is a Balint syndrome, due to suspected bilateral occipitoparietal dysfunction, and consonant with a diagnosis of VVAD.

Neuroimaging Studies—We undertook two neuroimaging studies of patient 2354, conducted contemporaneously with the experimental procedures reported below (at the time of the second neuropsychological assessment). One was a structural study (MRI), and the other was a metabolic study (FDG-PET).

A high-resolution MRI of the brain demonstrated posterior cortical atrophy (Figure 2). The images in Figure 2 show that there is severe but remarkably circumscribed atrophy in the occipitoparietal region. The atrophy involves the dorsal, superior aspects of the visual association cortices (Brodmann areas 18/19), and extends into the anteriorly adjacent superior parietal lobule to affect Brodmann area 7. The primary visual cortices appear unaffected, and there is no notable atrophy elsewhere in the brain (including the medial temporal lobe, which we looked at carefully). The occipitoparietal atrophy is bilateral, and is squarely within the areas that are commonly affected in patients with Balint syndrome.

A resting FDG-PET study revealed occipital, parietal, and, to a lesser degree, temporal lobe hypometabolism. Of note, the primary visual cortex (area 17) was spared. The FDG-PET study was interpreted by the radiologist as showing decreased cortical activity bilaterally in the occipital and parietal lobes, consistent with the condition of VVAD, and further confirmed by the literature (cf. Nestor et al., 1993; Pietrini et al., 1996). It was estimated that the reduction in cortical metabolic activity in the occipital-parietal region was some 30 to 40 percent, relative to metabolic activity in the frontal lobes (what can be considered a major decrease in resting metabolic activity in these posterior-superior regions). We should note that a detailed quantitative analysis of the FDG-PET study was not performed, and hence, we are adding the PET information as a secondary source of convergent support for the notion that our patient has occipitoparietal dysfunction. The structural MRI data are more straightforward, and should be considered the primary evidence for the neuroanatomical claims we are setting forth for patient 2354.

Investigation of Nonconscious Recognition

Stimuli and Procedure—We turn now to the primary experiment in this study, which involved an adaptation of previous methodology (Tranel & Damasio, 1985) to investigate the phenomenon of nonconscious visual recognition in patient 2354. This experiment was conducted at the same time as the second neuropsychological assessment mentioned above. Specifically, we conducted an experimental task in which patient 2354 was presented 20 neutrally- and 20 negatively-valenced visual stimuli, selected from the International Affective Picture System (IAPS; Lang et al., 1999). For half of the stimuli (i.e., 10 negative and 10 neutral), the pictures were displayed for 2 seconds each, and for the other half (the other 10 negative and 10 neutral), the stimuli were shown for 5 seconds each. The 2-second and 5-second exposures were conducted in serial order (with the 2-second experiment first). The rationale for using two different exposure times was simply to provide differing time windows for patient 2354 to apprehend and respond to the pictures, and we did not have any hypothesis or prediction regarding exposure time per se.

For each stimulus, patient 2354 was instructed to view the picture carefully. For each picture, following the 2- or 5-second display (i.e., after picture offset), patient 2354 was asked to rate the valence of the stimulus on a 5-point Likert scale ranging from unpleasant (1) to pleasant (5) (with neutral corresponding to “3” on the scale). Finally, she was asked to identify the picture, if she could, with a verbal description. No time limits were imposed for the valence ratings or for the verbal descriptions. The verbal descriptions were recorded verbatim by the experimenter, and prepared for data analysis (see below). There was about 30 to 40 seconds between stimuli for both the 2-second and 5-second presentations. The experimenter controlled the presentation of the stimuli, and the next stimulus was not presented until the patient had performed the valence ratings and verbal descriptions. The interstimulus interval thus varied somewhat, and was allowed to be longer if the patient was still making an effort to identify and describe the stimulus (up to about 50 seconds), so as to reduce any pressure the patient might feel to hurry her responses. On average, the interstimulus interval hovered around 30 to 40 seconds, and it did not vary systematically as a function of the valence of a particular stimulus.

Skin conductance was recorded during presentation of the 40 pictures. Specifically, SCRs were recorded from two Ag/AgCl electrodes attached to the thenar and hypothenar eminences of each hand. The signal was recorded at 500 Hz using a Biopac (Biopac Systems, Santa Barbara, CA) MP150 system including amplifiers for SCR collection.

Data Analysis

The first step of the data analysis involved examining the 40 pictures and patient 2354's responses to find those which she had identified accurately with her verbal descriptions (this was done from the verbatim descriptions by an investigator who was blind to the SCR results). There were 6 of these, and we removed these stimuli from further consideration, as they are not interesting vis-à-vis the primary experimental question—that is, we were interested in recognition without awareness, and for stimuli that patient 2354 identified properly at an overt, conscious level, the phenomenon of recognition without awareness is not applicable. It should be noted that in keeping with her severe simultanagnosia, patient 2354 failed to identify accurately most of the pictures (overall, she missed 34/40 pictures), and produced verbal descriptions typical of patients with simultanagnosia. For example, for a picture of a burned child, she said, “Some red color, I can't see what he is doing.” She rated this as “neutral” (3). For a picture of a fireman rescuing a burning woman, she responded, “They are dog-piling, messing around.” She also rated this picture as “neutral” (3).

We grouped the remaining stimuli into three categories, based on how patient 2354 had responded to them on the Likert rating scale of valence. (1) *Emotional-Covert*: This category included negative emotional pictures that patient 2354 had (incorrectly) rated as “neutral” (or pleasant), suggesting inaccurate perception. (It should be noted that the valence of the emotional pictures is not subtle—these pictures have been extensively utilized in previous research and are robust elicitors of negative emotional responses. In fact, we selected from the IAPS what we judged to be some of the most potent negative pictures.) (2) *Emotional-Overt*: This category included negative emotional pictures that patient 2354 correctly rated as “unpleasant,” suggesting some degree of accurate perception (even without accurate identification). (3) *Neutral-Overt*: This category included neutral pictures that patient 2354 correctly rated as “neutral,” suggesting some degree of accurate perception (even without accurate identification). There were 4 additional stimuli that did not fit into any of these three categories, e.g., neutral stimuli that were rated as pleasant, and we omitted these from the data analysis—hence, after removing these 4 stimuli, there remained 30 stimuli that fit into the three different classification categories. Specifically, we had the following numbers of stimuli in the final data analysis: Emotional-Covert; N = 10 (5 2-second, 5 5-second); Emotional-Overt; N = 10 (5 2-second, 5 5-second); and Neutral-Overt, N = 10 (6 2-second, 4 5-second).

Based on our standard method (see Tranel, Fowles, & Damasio, 1985), for each picture, the amplitude of the largest SCR that began within 1 to 5 seconds after stimulus onset was measured and recorded for each hand, and we averaged SCR amplitudes from the left hand with those from the right hand to generate a single SCR amplitude value for each picture. These were summed across the three different stimulus categories (as defined above), for each of the 2-second and 5-second exposure sets. We then calculated the average SCR amplitudes (magnitudes) for the three stimulus categories, and compared these statistically with a one-way repeated measures analysis of variance (ANOVA), collapsing across the 2-second and 5-second sets (which yields N's of 10 for each of the 3 categories as defined above).

We predicted that patient 2354 would evince significantly larger SCRs to the negative stimuli than to the neutral stimuli, and that this effect would occur in the absence of conscious recognition—specifically, her SCRs would be comparable for the Emotional-Covert stimuli and for the Emotional-Overt stimuli, and in both cases larger than for the Neutral-Overt stimuli. As mentioned earlier, we did not have a prediction about the exposure time, and we predicted that the above effect [Emotional-Covert = Emotional-Overt > Neutral-Overt] would hold for both the 2-second and 5-second exposure sets.

RESULTS

Figures 3 and 4 depict the results of patient 2354's SCRs to pictures in the 2-second and 5-second exposure sets, respectively. Both Figures show the same fundamental pattern of results. Overall, the average SCR amplitudes for the negative stimuli were substantially larger than for the neutral stimuli. It can be seen from the Figures that patient 2354 demonstrated high amplitude SCRs to the negative emotional stimuli whose valence she recognized correctly (Emotional-Overt), whereas her SCRs to the neutral stimuli whose valence she recognized correctly (Neutral-Overt) were near zero. The striking and novel finding was that for the stimuli for which patient 2354 did not recognize the valence accurately (i.e., emotional pictures that she rated as neutral or pleasant), she nevertheless generated high-amplitude SCRs. For these stimuli (the Emotional-Covert sets), in fact, patient 2354's SCRs were somewhat larger than for the emotional stimuli that she had recognized the valence of accurately (Emotional-Overt).

Figure 5 has the results depicted collapsed across exposure times, and the patterns here are the same as those described immediately above. Specifically, the SCRs for Emotional-Covert and Emotional-Overt sets are much higher than those for the Neutral-Overt set, and the two

Emotional sets do not differ very much. It is also interesting that the SCR magnitude for the Emotional-Covert pictures was actually somewhat higher than for the Emotional-Overt pictures. The data in Figure 5 were subjected to formal statistical analysis using a one-way repeated measures ANOVA. The overall ANOVA was significant ($F(2,18) = 10.53, p = .004$). Planned comparisons yielded the following outcomes: Emotional-Covert significantly differed from Neutral-Overt ($F(1,9) = 16.74, p = .003$); Emotional-Overt significantly differed from Neutral-Overt ($F(1,9) = 25.07, p = .001$); and Emotional-Covert and Emotional-Overt did not significantly differ ($F(1,9) = 1.78, p = .22$). (We did not analyze the data separately as a function of stimulus exposure time, since we did not have predictions for this factor.)

For purposes of illustration, examples of patient 2354's skin conductance responses to two negative emotional pictures are shown in Figures 6A and 6B. The Figures show that for two emotional pictures that 2354 failed to recognize overtly, and rated as being "neutral" in affective valence, she generated large-amplitude SCRs from both the right and left hands (the example in Figure 6A is from the 2-second exposure, and the example in Figure 6B is from the 5-second exposure).

DISCUSSION

We have shown in the current study that a patient with severe simultanagnosia, whose visual processing impairment prevents her from appreciating blatant negative emotional content in many visual stimuli, can nonetheless demonstrate covert or nonconscious recognition of the affective valence of those stimuli, as evidenced in her large amplitude SCRs to negatively-charged pictures that she rated as being affectively "neutral." This effect was striking and compelling: patient 2354 could look carefully at a picture of a burned and bloodied child, only report seeing a "red color," rate the picture as "neutral," but produce a very large skin conductance response. In its essence, this phenomenon is similar to what we have observed in previous experiments with prosopagnosic patients, where a patient could look carefully at a picture of themselves, report not recognizing the face nor having any sense of familiarity, but generate a large skin conductance response. These phenomena are especially striking in the context of the actual experiments, where the behavior of the patients almost defies belief. Specifically, the patient looks carefully at a stimulus with obvious "signal value," reports no sense of recognition of the implied meaning of the stimulus, but generates a large SCR. The phenomenon has appropriately been termed "recognition without awareness," and we would ascribe the same descriptor to the behavior of patient 2354.

As summarized in the Introduction, preserved "implicit" visual processing has been reported before in a few cases of simultanagnosia and dorsal stream visual dysfunction, although all of those prior studies relied on behavioral measures to detect the preserved implicit processing in their patients (Coslett & Saffran, 1991; Coslett et al., 1995; Filoteo et al., 2002; Stark et al., 1997; Wojciulik & Kanwisher, 1998). Thus, the current report is the first time, to our knowledge, that a psychophysiological index has been used to demonstrate implicit visual processing—what we are calling "recognition without awareness"—in a patient with simultanagnosia. Our case thus helps to expand the empirical base for the phenomenon of recognition without awareness in dorsal visual stream dysfunction, and more generally, the empirical base for the phenomenon of recognition without awareness per se. This phenomenon has not gone without challenges, and the availability of convergent sources of evidence is important for holding the phenomenon to a firm empirical footing. In particular, Pessoa and Ungerleider (2004) have taken a strong position that visual stimulus processing outside of the focus of attention is almost always highly attenuated or abolished, even for emotionally-laden stimuli, and our current findings would appear to argue against this view, or at least constitute a notable exception.

In a thorough review of many different aspects of Balint syndrome, Rafal (2001) noted that implicit measures of processing in Balint syndrome, as in the behavioral studies adduced above, have yielded strong evidence for extensive processing of visual information outside of conscious awareness. Rafal grouped these implicit phenomena under the rubric of “preattentive visual processing,” and enumerated a number of different facets of this phenomenon: preattentive representation of space (e.g., a spatial Stroop interference effect, as shown in the case of Robertson et al., 1997); preattentive grouping of features (e.g., effects of connectedness, brightness, and collinearity, as shown by Humphreys, 1998); preattentive processing of depth (e.g., sensitivity to occlusion cues, as shown in the case of Humphreys, 1998); preattentive processing of global information (e.g., an effect of global-local congruence, as in the case of Filoteo et al., 2002); and even preattentive processing of the meanings of words (e.g., an influence of the semantic relatedness of words, as shown by the case of Coslett and Saffran, 1991). Our case adds an important theme to this list: an influence of *emotional content*. Given our findings, this could be considered another example of “preattentive” visual processing, in the manner proposed by Rafal (2001). In other words, the emotional connotation of a nonverbal visual stimulus can influence downstream processing in the absence of conscious awareness in patient 2354, leading to a physiological change (increased skin conductance) that is characteristic of an orienting or “arousal” response. This implies the integrity of a pathway from higher order visual cortices to autonomic effectors in, for example, the medial temporal lobe (amygdala) and/or hypothalamus. In fact, there are robust (multi-step) anatomical connections between visual cortices and amygdala, especially in the occipitotemporal ventral stream system that contains the inferior longitudinal fasciculus, and there are also feedback connections from amygdala to visual cortices (e.g., Amaral et al., 1992; Frees & Amaral, 2005), as well as evidence of bidirectional functional connectivity between the amygdala and higher-order visual cortices (e.g., Vuilleumier et al., 2004). Another possibility is that the influence could be subserved via a subcortical route, e.g., through the superior colliculus to the amygdala (akin to the retino-collicular-pulvinar-amygdala pathway proposed by Morris et al., 1999), and it could even be that both of these pathways are operative in allowing an emotion-laden visual stimulus to influence autonomic responsiveness.

It is interesting to situate this latter idea in the context of evidence from other sources, which has indicated an effect of emotional facial expressions on aspects of visual attention (e.g., Adolphs et al., 2001; Fox, 2002; Vuilleumier & Schwartz, 2001). More generally, several studies have supported the idea that emotion can facilitate visual attention (e.g., Anderson & Phelps, 2001; Öhman et al., 2001), and in some of the paradigms in this literature, these effects have been reported to occur below the level of conscious awareness. Another related finding is that positive emotional facial expressions can facilitate the identification of famous faces (Gallegos & Tranel, 2005)—e.g., a “smiling” version of Julia Roberts is identified faster than a neutral version. A proposed neural mechanism for the effects of emotion on visual attention and visual processing more generally is a feedback influence from the amygdala to higher-order visual cortices, which would support a modulatory influence of the amygdala on extrastriate cortex (e.g., Adolphs et al., 1996; Anderson & Phelps, 2001; Morris et al., 1998; Sato et al., 2001). Again, in many of the relevant studies cited here, these effects are apparent especially or even only at a nonconscious level, which suggests interesting parallels with the phenomenon we uncovered in patient 2354. In any event, the dissociation between impaired conscious recognition and preserved, discriminatory SCRs in patient 2354 suggests that the physiological process of recognition of affective valence is still taking place, but that the results of its operation are not made available to conscious awareness.

There are limitations in our study, and we offer the evidence as preliminary and in need of replication, given that we are reporting a single case. One important issue to address in interpreting the current findings is to ensure that patient 2354’s discriminatory SCRs were not due to misperceptions alone. SCR is an autonomic variable that may be responsive to any

number of “emotional” factors (e.g., frustration), and it is plausible that patient 2354’s confusion or frustration over what she was attempting to perceive would be sufficiently upsetting to produce elevated SCRs. However, the contrast of the Emotional-Overt and Neutral-Overt conditions helps discount this possibility: 2354 generated large-amplitude SCRs only in the Emotional-Overt condition (and not in the Neutral-Overt one), making it seem unlikely that frustration per se would be the factor prompting the discriminatory SCRs. Also, we do not want to imply that dorsal visual stream dysfunction is the only evidence of brain dysfunction in patient 2354. While this was clearly the most atrophic part of her brain per structural MRI, and the clinical presentation was very congruent (Balint syndrome), the patient had a degenerative process, and she did have neuropsychological evidence of more widespread dysfunction, e.g., memory weakness suggestive of possible medial temporal lobe involvement (although there was no gross atrophy in the medial temporal lobe). We are not staking any claims here to a strict brain-behavior relationship, but merely emphasizing that the patient demonstrated preserved recognition without awareness in the face of significant dorsal stream visual dysfunction. Another limitation is that we did not investigate positively-valenced stimuli, so we do not know if the phenomenon manifested by patient 2354 would extend to positive emotions, although we suspect that it would. Finally, as noted, this is a single patient, and additional cases will be important to establish that the phenomenon of recognition without awareness derived from a psychophysiological index can be replicated in additional patients with Balint syndrome and dorsal visual stream damage.

The central and peripheral sectors of the nervous system are intimately connected, and bidirectional influences abound and are especially important in the domain of emotional processing. Our case of recognition without awareness, based on skin conductance responses in a patient with Balint syndrome, adds to an intriguing body of work that has shown how important peripheral somatic information is to the central processing of emotion, and to other aspects of cognitive processing (cf. Damasio, 1994). Many of the other investigations reported in the Special Issue of the *International Journal of Psychophysiology* underscore this same message.

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References

- Adolphs R, Damasio H, Tranel D, Damasio AR. Cortical systems for the recognition of emotion in facial expressions. *Journal of Neuroscience* 1996;16:7678–7687. [PubMed: 8922424]
- Adolphs R, Jansari A, Tranel D. Hemispheric perception of emotional valence from facial expressions. *Neuropsychology* 2001;15:516–524. [PubMed: 11761041]
- Amaral, DG.; Price, JL.; Pitkanen, A.; Carmichael, ST. Anatomical organization of the primate amygdaloid complex. In: Aggleton, J., editor. *The amygdala: Neurobiological aspects of emotion, memory, and mental dysfunction*. New York: Wiley-Liss; 1992. p. 1-66.
- Anderson AK, Phelps EA. Lesions of the human amygdala impair enhanced perception of emotionally salient events. *Nature* 2001;411:305–309. [PubMed: 11357132]
- Bauer RM. Autonomic recognition of names and faces in prosopagnosia: A neuropsychological application of the Guilty Knowledge Test. *Neuropsychologia* 1984;22:457–469. [PubMed: 6483172]
- Bauer RM, Verfaellie M. Electrodermal discrimination of familiar but not unfamiliar faces in prosopagnosia. *Brain and Cognition* 1988;8:240–252. [PubMed: 3196486]
- Benson DF, Davis RJ, Snyder BD. Posterior cortical atrophy. *Archives of Neurology* 1988;45:789–793. [PubMed: 3390033]

- Benton, AL.; Hamsher, K. Multilingual Aphasia Examination. Iowa City, Iowa: University of Iowa; 1978. (Manual, revised)
- Benton, AL.; Sivan, AB.; Hamsher, KS.; Varney, NR.; Spreen, O. Contributions to Neuropsychological Assessment. New York: Oxford University Press; 1994.
- Coslett HB, Saffran E. Simultanagnosia: To see but not two see. *Brain* 1991;114:1523–1545. [PubMed: 1884165]
- Coslett HB, Stark M, Ragaram S, Saffran EM. Narrowing the spotlight: A visual attentional disorder in presumed Alzheimer's disease. *Neurocase* 1995;1:305–318.
- Damasio, AR. Descartes' error: Emotion, reason, and the human brain. New York: Grosset/Putnam; 1994.
- Damasio, AR.; Tranel, D.; Rizzo, M. Disorders of complex visual processing. In: Mesulam, MM., editor. *Principles of Behavioral Neurology*. New York: Oxford University Press; 2000. p. 332-3728.
- de Haan EH, Young A, Newcombe F. Faces interfere with name classification in a prosopagnosic patient. *Cortex* 1987;23:309–316. [PubMed: 3608524]
- Farah MJ, Feinberg TE. Consciousness of perception after brain damage. *Seminars in Neurology* 1997;17:145–152. [PubMed: 9195657]
- Filoteo V, Friedrich FJ, Rabbel C, Stricker JL. Visual perception without awareness in a patient with posterior cortical atrophy: Impaired explicit but not implicit processing of global information. *Journal of the International Neuropsychological Society* 2002;8:461–472. [PubMed: 11939703]
- Fox E. Processing emotional facial expressions: The role of anxiety and awareness. *Cognitive, Affective, & Behavioral Neuroscience* 2002;2:52–63.
- Frees JL, Amaral DG. The organization of projections from the amygdala to visual cortical areas TE and V1 in the macaque monkey. *The Journal of Comparative Neurology* 2005;486:295–317. [PubMed: 15846786]
- Gallegos D, Tranel D. Positive facial affect facilitates the identification of famous faces. *Brain and Language* 2005;93:338–348. [PubMed: 15862858]
- Goodglass, H.; Kaplan, E.; Barresi, B. *The Assessment of Aphasia and Related Disorders*. Vol. 3. Philadelphia: Lea & Febiger; 2000.
- Graff-Radford NR, Bolling JP, Earnest F, Shuster EA, Caselli RJ. Simultanagnosia as the initial sign of degenerative dementia. *Mayo Clinic Proceedings* 1993;68:955–964. [PubMed: 8412361]
- Humphreys GW. Neural representation of objects in space: a dual coding account. *Philosophical Transactions of the Royal Society of London Series B: Biological Sciences* 1998;353:1341–1351.
- Husain M, Stein J. Rezso Balint and his most celebrated case. *Archives of Neurology* 1988;45:89–93. [PubMed: 3276300]
- Jones RD, Tranel D. Severe developmental prosopagnosia in a child with superior intellect. *Journal of Clinical and Experimental Neuropsychology* 2001;23:265–273. [PubMed: 11404805]
- Kaplan, EF.; Goodglass, H.; Weintraub, S. *The Boston Naming Test*. Vol. 3. Austin: PRO-ED, Inc; 2001.
- Knight, JA.; Kaplan, EG. *The Handbook of Rey-Osterrieth Complex Figure Usage: Clinical and Research Applications*. Lutz, FL: Psychological Assessment Resources, Inc; 2004.
- Lang, PJ.; Bradley, MM.; Cuthbert, BN. *The Center for Research in Psychophysiology*. University of Florida; Gainesville, FL: 1999. *International affective picture system (IAPS): Instruction manual and affective ratings*.
- Lazarus RS, McCleary RA. Autonomic discrimination without awareness: A study of subception. *Psychological Review* 1951;58:113–122. [PubMed: 14834294]
- Lezak, MD.; Howieson, DB.; Loring, DW. *Neuropsychological Assessment*. Vol. 4. New York: Oxford University Press; 2004.
- Mendez MF. Corticobasal ganglionic degeneration with Balint's syndrome. *Journal of Neuropsychiatry and Clinical Neuroscience* 2000;12:273–275.
- Mendez MF, Chierri MM. The evolution of alexia and simultanagnosia in posterior cortical atrophy. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology* 1998;11:76–82.
- Mendez MF, Ghajarania M, Perryman KM. Posterior cortical atrophy: Clinical characteristics and differences compared to Alzheimer's disease. *Dementia and Geriatric Cognitive Disorders* 2002;14:33–40. [PubMed: 12053130]

- Mesulam, MM. Aging, Alzheimer's disease, and dementia: Clinical and neurobiological perspectives. In: Mesulam, MM., editor. *Principles of Behavioral and Cognitive Neurology*. New York: Oxford University Press; 2001. p. 439-522.
- Morris JS, Öhman A, Dolan RJ. Conscious and unconscious emotional learning in the human amygdala. *Nature* 1998;393:467-470. [PubMed: 9624001]
- Morris JS, Öhman A, Dolan RJ. A subcortical pathway to the right amygdala mediating "unseen" fear. *Proceedings of the National Academy of Sciences USA* 1999;96:1680-1685.
- Nestor PJ, Caine D, Fryer TD, Clarke J, Hodges JR. The topography of metabolic deficits in posterior cortical atrophy (the visual variant of Alzheimer's disease) with FDG-PET. *Journal of Neurology, Neurosurgery, and Psychiatry* 2003;74:1521-1529.
- Öhman A, Flyky A, Esteves F. Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General* 2001;130:466-478. [PubMed: 11561921]
- Pessoa L, Ungerleider LG. Neuroimaging studies of attention and the processing of emotion-laden stimuli. *Progress in Brain Research* 2004;144:171-182. [PubMed: 14650848]
- Pietrini P, Furey ML, Graff-Radford N, Freo U, Alexander GE, Grady CL, Dani A, Mentis MJ, Schapiro MB. Preferential metabolic involvement of visual cortical areas in a subtype of Alzheimer's disease: Clinical implications. *American Journal of Psychiatry* 1996;153:1261-1268. [PubMed: 8831432]
- Rafal, R. Balint's syndrome. In: Boller, F.; Grafman, J., editors. *Handbook of Neuropsychology*. Vol. 4. Amsterdam: Elsevier Science; 2001. p. 121-141.
- Reiser MF, Block JD. Discrimination and recognition of weak stimuli. 3. Further experiments on interaction of cognitive and autonomic-feedback mechanisms. *Psychosomatic Medicine* 1965;27:274-285. [PubMed: 14327879]
- Reitan, RM.; Wolfson, D. *The Halstead-Reitan Neuropsychological Test Battery*. Tuscon: Neuropsychology Press; 1985.
- Rey, A. *L'examen Clinique en psychologie*. Paris: Presses Universitaires de France; 1964.
- Rizzo, M. "Balint's syndrome" and associated visuospatial disorders. In: Hennard, C., editor. *Bailliere's International Practice and Research*. London: W.B. Saunders; 1993. p. 415-437.
- Rizzo M, Hurtig R. Looking but not seeing: Attention, perception, and eye movements in simultanagnosia. *Neurology* 1987;37:1642-1648. [PubMed: 3658172]
- Robertson L, Treisman A, Friedman-Hill S, Grabowecky M. The interaction of spatial and object pathways: evidence from Balint's syndrome. *Journal of Cognitive Neuroscience* 1997;9:254-276.
- Rousey C, Holzman PS. Recognition of one's own voice. *Journal of Personality and Social Psychology* 1967;6:464-466. [PubMed: 6082480]
- Sato W, Kochiyama T, Yoshikawa S, Matsumura M. Emotional expression boosts early visual processing of the face: ERP recording and its decomposition by independent component analysis. *NeuroReport* 2001;12:709-714. [PubMed: 11277569]
- Sivan, AB. *The Benton Visual Retention Test*. Vol. 5. New York: Psychological Corporation; 1991.
- Stark ME, Grafman J, Fertig E. A restricted 'spotlight' of attention in visual object recognition. *Neuropsychologia* 1997;35:1233-1249. [PubMed: 9364494]
- Tranel, D. Theories of clinical neuropsychology and brain-behavior relationships: Luria and beyond. In: Morgan, JE.; Ricker, JH., editors. *Textbook of clinical neuropsychology*. New York: Taylor and Francis; 2007. p. 27-39.
- Tranel D, Damasio AR. Knowledge without awareness: An autonomic index of facial recognition by prosopagnosics. *Science* 1985;228:1453-1454. [PubMed: 4012303]
- Tranel D, Damasio AR. Nonconscious face recognition in patients with face agnosia. *Behavioural Brain Research* 1988;30:235-249. [PubMed: 3178995]
- Tranel D, Fowles DC, Damasio AR. Electrodermal discrimination of familiar and unfamiliar faces: A methodology. *Psychophysiology* 1985;22:403-408. [PubMed: 4023151]
- Victoroff J, Ross W, Benson F, Verity A, Vinters HV. Posterior cortical atrophy: Neuropathologic correlations. *Archives of Neurology* 1994;51:269-274. [PubMed: 8129638]
- Viggiano MP. Event-related potentials in brain-injured patients with neuropsychological disorders: A review. *Journal of Clinical and Experimental Neuropsychology* 1996;18:631-647. [PubMed: 8941850]

- Vuilleumier P, Schwartz S. Emotional facial expressions capture attention. *Neurology* 2001;56:153–158. [PubMed: 11160948]
- Vuilleumier P, Richardson MP, Armony J, Driver J, Dolan RJ. Distant influences of amygdala lesion on visual cortical activation during emotional face processing. *Nature Neuroscience* 2004;7:1271–1278.
- Wechsler, DA. Wechsler Adult Intelligence Scale – III. New York: Psychological Corporation; 1997.
- Wilkinson, GS. Wide Range Achievement Test – 3. Wilmington, Delaware: Jastak Associates, Inc; 1993.
- Wojciulik W, Kanwisher N. Implicit but not explicit feature binding in a Balint’s patient. *Visual Cognition* 1998;5:157–181.

Figure 1.

Example of an item from the Boston Naming Test (wreath). For this item, patient 2354 responded to the question, “What is this?” by saying “bow,” not apprehending and appreciating that the entire drawing is of a “wreath.” Such a response is typical of patients with simultanagnosia.

Figure 2.

Structural magnetic resonance imaging (MRI) study of patient 2354. The top row shows left hemisphere (left), right hemisphere (middle), and superior (right) views, and the lower panel shows coronal sections taken at the levels indicated by the letters (a through f, anterior-to-posterior). The right hemisphere is on the left in the coronal sections, which were selected to show the striking but remarkably circumscribed cortical atrophy in the superior occipital, occipito-parietal, and upper parietal regions, bilaterally.

Skin Conductance Responses to Emotionally-Charged and Neutral Stimuli

Figure 3.

Patient 2354's skin conductance responses (in μ S) to Emotional-Covert, Emotional-Overt, and Neutral-Overt pictures for the 2-second stimulus exposure. The error bars indicate standard deviations. Notably, patient 2354 demonstrated large amplitude SCRs to emotionally charged pictures that she does not recognize at overt level.

Skin Conductance Responses to Emotionally-Charged and Neutral Stimuli

Figure 4.

Patient 2354's skin conductance responses (in μ S) to Emotional-Covert, Emotional-Overt, and Neutral-Overt pictures for the 5-second stimulus exposure. The error bars indicate standard deviations. Notably, patient 2354 demonstrated large amplitude SCRs to emotionally charged pictures that she does not recognize at overt level.

Figure 5.

Patient 2354's skin conductance responses (in μ S) to Emotional-Covert, Emotional-Overt, and Neutral-Overt pictures, collapsed across the 2-second and 5-second stimulus exposure. The error bars indicate standard deviations. Patient 2354 demonstrates large amplitude SCRs to emotionally charged pictures that she does not recognize at overt level.

Figure 6.

(A) Example of SCRs in patient 2354, in response to a picture of a burned child. The patient failed to recognize the picture and described it as, “Some red color, I can’t see what he is doing.” She rated the picture as “neutral” in valence. The time marker channel is at the top, and the downward tick indicates the onset of the picture exposure (which was for 2 seconds). SCRs from the right hand (upper trace) and left hand (lower trace) began within about a second, and very large amplitude SCRs occurred in both hands in response to the picture.

(B) Example of SCRs in patient 2354, in response to a picture of a fireman rescuing a burning woman. The patient failed to recognize the picture and described it as, “They are dog-piling, messing around.” She rated the picture as “neutral” in valence. The time marker channel is at the top, and the downward tick indicates the onset of the picture exposure (which was for 5 seconds). SCRs from the right hand (upper trace) and left hand (lower trace) began within about a second, and very large amplitude SCRs occurred in both hands in response to the picture.

Table 1

NEUROPSYCHOLOGICAL DATA	TIME 1	TIME 2
Orientation	Intact	Intact
WAIS Digit Span (SS)	6 (low average)	6 (low average)
WAIS Vocabulary (SS)	6 (low average)	--
WAIS Similarities (SS)	8 (average)	--
WAIS Comprehension (SS)	8 (average)	7 (low average)
WAIS Picture Completion (SS)	3 (extremely low)	4 (borderline)
AVLT – Trials 1-5/Delay	3-7-8-9-10/7	2-4-5-9-9/6
Visual Memory	Discontinued	Discontinued
Phonemic Verbal Fluency	20 (defective)	18 (defective)
Boston Naming Test	29/60 (defective)	36/60 (defective)
BDAE Responsive Naming	29/30 (normal)	--
Trail Making Tests A & B	Discontinued	Discontinued
Benton Facial Discrimination	Severely Impaired	Severely Impaired
Visuoconstruction	Impaired	Impaired
Reading	Impaired	Impaired
Writing	Borderline	Borderline
Praxis	Intact	Intact
Expressive Speech	Intact	Intact
Color Naming	Intact	Intact

Shown are raw scores or level of impairment for various neuropsychological tests and functions. Missing values (--) or discontinued tests (discontinued means that the patient was unable to complete the task, and thereby, it can be inferred that she was impaired) are indicated. Shown are Orientation to person, place, and time; selected subtests from the Wechsler Adult Intelligence Scale-III (WAIS-III; Wechsler, 1997) in scaled scores (mean of 10 and standard deviation of 3) including Digit Span (attention and working memory), Vocabulary (semantic word knowledge), Similarities (verbal abstraction), Comprehension (social judgment), and Picture Completion (attention to visual details); anterograde verbal memory as measured by the Rey Auditory-Verbal Learning Test learning trials 1–5 (number of words recalled out of 15 total) and 30 minute delayed recall (Rey, 1964); visual memory as measured by the Benton Visual Retention Test (Sivan, 1991) and memory condition of the Rey-Osterrieth Complex Figure Test (Knight & Kaplan, 2004); verbal fluency as measured by the Controlled Oral Word Association Test (C, F, L; Benton & Hamsher, 1978); confrontation naming as measured by the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 2001) and the BDAE Responsive Naming (Goodglass, Kaplan, & Barresi, 2000); executive functioning as measured by the Trail Making Tests A & B (Reitan & Wolfson, 1985); visuoconstruction as measured by the Benton Facial Discrimination Test (Benton et al., 1994); visuoconstruction as measured by the Clock Drawing Test (Lezak, Howieson, & Loring, 2004) and the copy condition of the Rey-Osterrieth Complex Figure Test (Knight & Kaplan, 2004); reading as measured by WRAT-3 Reading subtest (Wilkinson, 1993); and writing, praxis, expressive speech, and color naming as measured by standard clinical procedures of the Benton Neuropsychology Laboratory (Tranel, 2007).