Behav Res (2015) 47:228–234
DOI 10.3758/s13428-014-0464-0

Generating an item pool for translational social cognition research: Methodology and initial validation

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Published online: 10 April 2014

Abstract Existing sets of social and emotional stimuli suitable for social cognition research are limited in many ways, including size, unimodal stimulus delivery, and restriction to major universal emotions. Existing measures of social cognition could be improved by taking advantage of item response theory and adaptive testing technology to develop instruments that obtain more efficient measures of multimodal social cognition. However, for this to be possible, large pools of emotional stimuli must be obtained and validated. We present the development of a large, high-quality multimedia stimulus set produced by professional adult and child actors (ages 5 to 74) containing both visual and vocal emotional expressions. We obtained over 74,000 audiovisual recordings of a wide array of emotional and social behaviors, including the main universal emotions (happiness, sadness, anger, fear, disgust, and surprise), as well as more complex social expressions (pride, affection, sarcasm, jealousy, and shame). The actors generated a high quantity of technically superior, ecologically valid stimuli that were digitized, archived, and rated for accuracy and intensity of expressions. A subset of these facial and vocal expressions of emotion and social behavior were submitted for quantitative ratings to generate parameters for validity and discriminability. These stimuli are suitable for affective neuroscience-based psychometric tests, functional neuroimaging, and social cognitive rehabilitation programs. The purposes of this report are to describe the method of obtaining and validating this database and to make it accessible to the scientific community. We invite all those interested in participating in the use and validation of these stimuli to access them at www.med.upenn.edu/bbl/actors/index.shtml.

Keywords Social cognition · Emotion · Affect · Stimuli · Faces · Audiovisual · Recordings

Deficits in social cognition and affective processing are prominent features of multiple mental disorders, including schizophrenia and autism. Previous studies have attempted to elucidate the mechanisms underlying affective processing and social cognition by using a variety of approaches, many of which involve the presentation and manipulation of facial stimuli. Furthermore, many studies using facial affective stimuli have involved systematic manipulation of facial features by methods including spatial frequency (Vuilleumier, Armony, Driver, & Dolan, 2003; Winston, Vuilleumier, & Dolan, 2003), binocular suppression (Williams, Morris, McGlone, Abbott, & Mattingley, 2004), chimeric faces (Morris, deBonis, & Dolan, 2002), masked fearful eye whites (Whalen et al., 2004), and gaze direction (Adams & Kleck, 2003; Adolphs, Sears, & Piven, 2001).

Since this research has focused primarily on the visual domain, the existing databases of facial stimuli consist mainly of static photographs of affective poses (e.g., Ekman & Friesen, 1976; Gur et al., 2002; Izard, 1971; Matsumoto & Ekman, 1988; Mazurski & Bond, 1993). The available stimuli are typically restricted to major universal emotions, such as happiness, sadness, anger, and fear. Although these stimuli have allowed investigators to probe emotional recognition

Electronic supplementary material The online version of this article (doi:10.3758/s13428-014-0464-0) contains supplementary material, which is available to authorized users.

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deficits in various disorders (e.g., Alfimova et al., 2009; Heimberg, Gur, Erwin, Shtasel, & Gur, 1992; Leentjens, Wielaert, van Harskamp, & Wilmink, 1998; Kerr & Neale, 1993), these disorders also typically involve deficits in affective processing and social cognition that can impair the perception of more complex and subtle emotional expressions. For example, children with autism show difficulty discussing socially derived emotions, such as embarrassment and pride (Capps, Yirmiya, & Sigman, 1992), whereas people with schizophrenia have difficulty with complex social judgments (Savla, Vella, Armstrong, Penn, & Twamley, 2012). In addition, different neural structures have been identified that subserve the comprehension of simple versus complex emotional expressions (Alba-Ferrara et al. 2011). Thus, existing databases of affective facial stimuli featuring static photographs of prototypical emotional expressions may lack the information to probe more subtle deficits in affective processing and social cognition or the interplay between the face and the voice that signals emotions in everyday discourse.

Vocal affect has been less well studied in the context of emotion processing in mental disorders (Edwards et al. 2002; Hoekert, Kahn, Pijnenborg, & Aleman, 2007; McCann & Peppe, 2003). When studies have examined both visual and auditory affect perception, they have commonly used combinations of differing tasks, and there is a lack of consistency among studies. Although most studies utilize audio-recorded sentences that vary in emotion, the tasks within each study often differ on the basis of type of emotion, gender of the actor conveying the emotion, and sentence type. Additionally, the use of multiple, varying measures can result in increased cognitive demands, which can lead to overestimation of individual impairment (Hoekert et al., 2007).

Currently existing databases of facial affective stimuli are often further limited by issues of size, novelty, and racial and ethnic diversity. This is particularly true even among currently available databases that do use dynamic stimuli (e.g., De Silva, Miyasato, & Nakatsu, 1997; Kaulard et al., 2012; Simon, Craig, Gosselin, Belin, & Rainville, 2008). Databases of computer-generated facial expressions suffer from similar limitations (e.g., Mower, Mataric, & Narayanan, 2009). Due to the scarcity of available stimuli and the increasing application of emotion recognition tests, existing tests have been exposed to large clinical and research populations. Furthermore, many available measures of emotion identification suffer from low discriminant validity (e.g., Haskins, Shutty, & Kellogg, 1995; Leentjens et al., 1998). Previous measures could be improved by taking advantage of item response theory and adaptive testing technology to develop instruments that obtain better measures of multimodal social cognition (Reise & Waller, 2009). However, for this to be possible, large pools of emotional stimuli must be obtained and validated.

In the present study, we present the development of a large, high-quality stimulus set produced by demographically diverse professional actors and containing both visual and vocal emotional expressions. We obtained visual, audio, and audio–visual recordings of actors expressing an array of emotional and social behaviors. The professional actors generated a high quality and quantity of ecologically valid stimuli that were digitized, archived, and rated for their accuracy and intensity of expressions.

These recordings were used to create a database of stimuli that will undergo continued study and validation, as well as be used in future affective neuroscience-based psychometric tests, functional neuroimaging, and social cognitive rehabilitation programs. The purposes of this report are to describe the method of obtaining and validating this database and to make it accessible to the scientific community. A subset of high-quality facial and vocal expressions of emotion and social behavior were submitted for quantitative ratings to generate preliminary parameters for validity and discriminability. The results of these ratings will also be described here.

Method

Acquisition of Actor Stimuli Database

Actor Recruitment and Demographics A sample of 150 adult and child actors of diverse ethnicities and ages across the lifespan (range: 5 to 74 years, mean age 36.1 ± 15.6 years) were recorded in order to create a database of high-quality audiovisual stimuli. The actors were recruited from advertisements, local theater organizations, and drama classes, and were auditioned by a professional theater director. Selected actors attended a recording session and were compensated for their time. Demographics of the actors are presented in the Table 1.

Recording Sessions Each actor was led through a structured emotional expression recording session by a professional theater director. Actors were asked to express a variety of emotions at a range of intensities (low, medium, and high) in response to scripted scenarios, which were verbally described to them by the director. Specific emphasis was placed on the main universal emotions (happiness, sadness, anger, fear, disgust, and surprise) as well as more complex social expressions (pride, affection, sarcasm, jealousy, and shame). The recording sessions typically lasted about 3 h for adult actors and 1 to 2 h for child and teenage actors (ages 5–17).

In the first part of the recording session, emotional prosody was expressed both verbally and nonverbally, through non-language utterances (e.g., "hmm," "huh," "ah," "ooh," "eee," "oh," and "sigh"), with words with neutral emotional valences (e.g., "really" and "sure"), and with sentences (e.g., "That is exactly what happened," "It's eleven o'clock.") from a set of validated neutral content statements (Russ, Gur, & Bilker,

Table 1 Actors' genders and races

	Male	Female
Adult Actors (*n* = 139)		
Caucasian	46	47
African American	15	14
Asian	6	8
Hawaiian/Pacific Islander	1	0
Other	0	1
Mixed/unknown	0	1
Child Actors (*n* = 11)		
Caucasian	1	4
African American	4	2
Asian	0	0
Hawaiian/Pacific Islander	0	0
Other	0	0
Mixed/unknown	0	0

2008). In addition, actors were recorded dynamically while quickly (for ~3 s apiece) posing from neutral to happy, sad, angry, fearful, disgusted, shameful, and surprised (pleasant, unpleasant, and startled) expressions. Social approval and disapproval (e.g., thumbs up/thumbs down) expressions and emotionally neutral gestures (e.g., snapping fingers while listening to headphones) were also acquired.

Static, posed expressions of happiness, sadness, anger, fear, surprise (pleasant, unpleasant, and startled), and disgust were also recorded. These included a brief video clip of a neutral expression and a series of static poses photographed with multiple orientations and gaze directions. Overall, 53 photos and 441 videos were collected for each actor. The completed database contains 74,100 stimuli. See Table 2 for details.

Equipment Recording sessions took place in a sound-attenuated environment with professional light boxes. Actors were seated against a green screen for ease of postproduction editing. Photographs were captured in digital negative format using a Canon Rebel T1i EF-S 18-55 IS Kit Digital SLR Camera (15.1 megapixels). Videos were recorded on a Panasonic AG-HPX170 at a resolution of 960 × 720 in the DVCPRO HD format using a story script created with the Adobe On Location software.

Initial Rating and Validation

Stimuli Sample Due to the large number of stimuli generated, initial validation was limited to a representative sampling of 152 visual stimuli (both still photos and videos without sound, either verbal or nonverbal) of low, medium, and high intensity, featuring expressions

Table 2 Breakdown of the total stimuli recorded

Expressions With Vocalizations		Expressions Without Vocalizations
Verbal	Nonverbal	
Sure.	"*hmm*"	Videos*
Really?	"*huh*"	Still photos
It's eleven o'clock.	"*sigh*"	
I'm on my way to the meeting.	"*ooh*"	
I wonder what this is about.	"*ahh*"	
Maybe tomorrow it will be cold.	"*eee*"	
The airplane is almost full.	"*ohh*"	
I would like a new alarm clock		
I think I have a doctor's appointment.		
Don't *forget a jacket.*		
I think I've seen this before.		
The surface is slick.		
We'll stop in a couple of minutes.		
That is exactly what happened.		
Each emotion was expressed at three intensities: low, medium, high.		
Emotions recorded for expressions with vocalizations: happy, sad, angry, fear, disgust, affection, jealousy, pleasure, pride, sarcasm, shame, and neutral.		
Emotions for expressions without vocalizations: happy, sad, angry, fear, disgust, shame, unpleasant surprise, pleasant surprise, and startled surprise.		

* Actors were recorded while expressionless and blinking their eyes naturally for the neutral emotion condition

of anger, happiness, sadness, fear, or neutrality. Still photo and video stimuli featured expressions from 26 adult actors (sex: 12 male, 14 female; race: 20 Caucasian, 5 African American, 1 Asian; ethnicity: 3 Hispanic, 23 non-Hispanic; mean age: 37.31 ± 12.69 years) were featured at varying lengths (500, 1,000, 1,500, or 2,000 ms). Because some emotions, like happiness, are recognized more easily than others (Gur et al., 2002), variable presentation lengths were used to ensure a range of difficulties of the items across all emotion categories. See Table 3 for details.

Stimuli were presented through a Web-based interface (programmed in Adobe Flash) for the initial validation testing. Photos and videos of all intensities (low, medium, and high) were included. After the presentation of each stimulus, participants were asked to identify the emotion that they believed the actor intended to express from among the following options: “happy,” “sad,” “anger,” “fear,” “neutral,” or “I don’t know.”

Participant Raters The participants were undergraduates at Drexel University (n = 226) and the University of Central Florida (n = 284) who rated stimuli using the Web interface. Trials with response times less than 300 ms were excluded, because such response times were either delayed responses from the previous trials or indicated lack of processing of the stimuli. Participants responding to fewer than 80 % of the trials (including trials excluded for response times <300 ms) were also excluded (n = 27).

Results

Accuracy

Accuracy, defined as congruence between the participant rating and the intended emotion of the actor, was calculated for

Table 3 Stimuli presented for ratings, by type, emotion, intensity, and presentation duration

	Still Photos (n = 71)					Videos (n = 81)				
	High	Medium	Low	N/A	Total	High	Medium	Low	N/A	Total
500 ms										
angry	2	2	0	–	4	3	3	0	–	6
fearful	2	1	2	–	5	1	2	3	–	6
happy	0	0	1	–	1	0	1	2	–	3
sad	4	3	1	–	8	2	4	0	–	6
neutral	–	–	–	6	6	–	–	–	5	5
total	8	6	4	6	24	6	10	5	5	26
1,000 ms										
angry	2	1	1	–	4	3	3	2	–	8
fearful	4	0	1	–	5	1	5	0	–	6
happy	1	0	4	–	5	0	1	1	–	2
sad	2	1	0	–	3	2	2	0	–	4
neutral	–	–	–	7	7	–	–	–	2	2
total	9	2	6	7	24	6	11	3	2	22
1,500 ms										
angry	4	0	1	–	5	2	0	2	–	4
fearful	1	3	0	–	4	4	2	1	–	7
happy	0	2	1	–	3	0	4	1	–	5
sad	2	0	0	–	2	3	2	0	–	5
neutral	–	–	–	5	5	–	–	–	5	5
total	7	5	2	5	19	9	8	4	5	26
2,000 ms										
angry	0	0	1	–	1	0	0	1	–	1
fearful	0	1	0	–	1	0	1	0	–	1
happy	0	0	0	–	0	0	0	3	–	3
sad	1	0	0	–	1	2	0	0	–	2
neutral	–	–	–	1	1	–	–	–	0	0
total	1	1	1	1	4	2	1	4	0	7
TOTAL	25	14	13	19	71	23	30	16	12	81

Table 4 Overall accuracy and accuracy by emotion for the total sample, the top 10 % of participants ("high performers"), and the lowest 10 % of participants ("low performers")

Accuracy	All Participants (n = 480)				High-Performers (n = 52)				Low-Performers (n = 48)			
	Mean	*SD*	Min	Max	Mean	*SD*	Min	Max	Mean	*SD*	Min	Max
Overall	.766	.096	.083	.928	.873	.017	.855	.928	.550	.128	.083	.664
By Emotion												
neutral	.799	.157	.000	1.000	.888	.070	.677	1.000	.591	.247	.000	1.000
happiness	.876	.115	.045	1.000	.933	.051	.818	1.000	.694	.220	.045	.955
anger	.740	.145	.030	1.000	.865	.062	.727	1.000	.503	.182	.030	.909
fear	.832	.129	.086	1.000	.921	.042	.800	1.000	.584	.190	.086	.914
sadness	.598	.155	.097	.935	.767	.102	.548	.935	.380	.152	.097	.774

Note that chance performance is about 16.7 % (100/6)

each participant. Overall, the accuracy across all stimuli was 77.5 % ± 8.3 %. Accuracy was highest for happy items (88.6 % ± 9.7 %), followed by fearful items (82.8 % ± 11.7 %), neutral items (79.4 % ± 15.3 %), angry items (75.1 % ±15.3 %), and finally sad items (62.8 % ± 13.7 %). See Table 4 for details.

Item Discrimination

Because emotions are inherently subjective, we sought to distinguish between items that were difficult to rate because they displayed the intended emotion, but at a level of intensity below threshold for individuals who were poor at judging emotions, and items that were difficult to rate because they failed to convey the intended emotion. To assess item discrimination, we examined whether items with lower response accuracy were identified better by participants with higher overall accuracy than by those with poorer overall accuracy. Participants were ranked by overall accuracy, and the means for both overall and by-emotion accuracy were calculated for the highest 10th percentile ("high performers," $n = 52$) and the lowest 10th percentile ("low performers," $n = 48$) of participants. Poor item discrimination was defined as those items for which performance does not differ significantly between high-performers and low-performers. See Table 4 for the averages of these groups.

Item-wise t tests between high performers and low performers were then implemented to assess item discrimination for each of the items. In this analysis, we tested the null hypothesis that the number of high-performing participants giving an accurate response to particular item did not differ from the number of low-performing participants answering that item accurately. These independent-samples t tests were significant ($p < .05$) for 94.7 % ($n = 144$) of the stimuli. Of the eight stimuli for which high-performers did not have significantly higher response accuracy, six of the stimuli were still photos (one for each emotion and two neutrals), and the other two were a high-intensity fearful video stimulus presented for 1,000 ms and a medium-intensity angry video stimulus presented for 500 ms. At a Bonferroni-corrected alpha threshold of $p = .0003$, 79.6 % of the stimuli ($n = 121$) still showed good item discrimination. See Fig. 1 for screen shots of items with high and low item discrimination.

Discussion

We have described the development of an emotive database composed of high-definition videos and photos that can be used to measure affect. These measures offer value to the

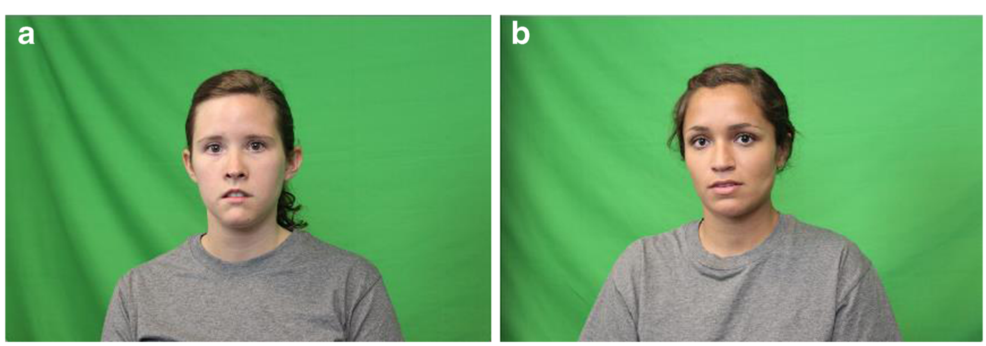

Fig. 1 Illustrative comparison clips. (**a**) High discriminant validity ($t = 12.22$, $p < .001$)—screenshot of a medium-intensity fearful video stimulus presented for 500 ms (left). (**b**) Low discriminant validity ($t = 1.81$, $p = .0728$ n.s.)—low-intensity fearful still photo stimulus presented for 1,000 ms (right)

scientific community due to the increased interest in social neuroscience and the impact of social cognition deficits in major psychiatric disorders including schizophrenia, autism, and other affective disorders. In addition, we have described data indicating that the stimuli collected in this manner show acceptable construct and discriminant validity. These results are encouraging, and suggest that this stimulus set is poised to become a valuable resource for the study of social cognition.

Notwithstanding the positive results obtained from this study, it has some limitations. Due to the restricted amount of time spent with each actor during recording sessions, it was difficult to obtain varying levels of intensity for each item measured. In addition, due to the large size of the data set, more work needs to be completed to validate the rest of the stimuli. This data collection is underway, utilizing both undergraduate and crowd-sourced samples. Further studies will examine the psychometric properties of each item in greater detail.

We believe that this set of socio-emotional stimuli can help facilitate progress in affective neuroscience. Such work can specifically help with the investigation of disorders such as schizophrenia and autism, as well as of affective disorders. It can also contribute to the elucidation of normal variation in affective processing and social cognition. The availability of such an item pool in the public domain can facilitate clinical and genomics research on normative and dysfunctional social cognition. These data could also be used to guide the development of computer software sensitive to emotional expressivity in the human voice. We invite all those interested in participating in the use and validation of these stimuli to access them at www.med.upenn.edu/bbl/actors/index.shtml. The only requirement is that research be done with the oversight of an ethics board.

Author note This work was supported by Grant Nos. NIH R01-MH060722 and NIH R01-MH084856. We thank our directors, Amy Dugas Brown and David M. O'Connor, and the Brain Behavior Laboratory staff, who edited the stimuli and provided Web programming support. The authors also recognize the work of Raymond P. Hill, who contributed significantly to the manuscript. Ray passed away in January 2013.

References

Adams, R. B., & Kleck, R. E. (2003). Perceived gaze direction and the processing of facial displays of emotion. *Psychological Science, 14,* 644–647.

Adolphs, R., Sears, L., & Piven, J. (2001). Abnormal processing of social information from faces in autism. *Journal of Cognitive Neuroscience, 13,* 232–240.

Alba-Ferrara, L., Hausmann, M., Mitchell, R. L., & Weis, S. (2011). The neural correlates of emotional prosody comprehension: Disentangling simple from complex emotion. *PLoS ONE, 6,* e28701. doi:10.1371/journal.pone.0028701

Alfimova, M. V., Abramova, L. I., Barhatova, A. I., Yumatova, P. E., Lyachenko, G. L., & Golimbet, V. E. (2009). Facial affect recognition deficit as a marker of genetic vulnerability to schizophrenia. *Spanish Journal of Psychology, 12,* 46–55.

Capps, L., Yirmiya, N., & Sigman, M. (1992). Understanding of simple and complex emotions in non-retarded children with autism. *Journal of Child Psychology and Psychiatry, 33,* 1169–1182.

De Silva, L. C., Miyasato, T., & Nakatsu, R. (1997). Facial emotion recognition using multi-modal information. *Information, Communications and Signal Processing, 1,* 397–401.

Edwards, J., Jackson, H. J., & Pattison, P. E. (2002). Emotion recognition via facial expression and affective prosody in schizophrenia: A methodological review. *Clinical Psychology Review, 22,* 789–832.

Ekman, P., & Friesen, W. V. (1976). *Pictures of facial affect*. Palo Alto: Consulting Psychologists Press.

Gur, R. C., Sara, R., Hagendoorn, M., Marom, O., Hughett, P., Turner, T., & Gur, R. E. (2002). A method for obtaining 3-dimensional facial expressions and its standardization for use in neurocognitive studies. *Journal of Neuroscience Methods, 115,* 137–143. doi:10.1016/S0165-0270(02)00006-7

Haskins, B., Shutty, J., & Kellogg, E. (1995). Affect processing in chronically psychotic patients: Development of a reliable assessment tool. *Schizophrenia Research, 15,* 291–297.

Heimberg, C., Gur, R. E., Erwin, R. J., Shtasel, D. L., & Gur, R. C. (1992). Facial emotion discrimination: III. Behavioral findings in schizophrenia. *Psychiatry Research, 42,* 253–265.

Hoekert, M., Kahn, R. S., Pijnenborg, M., & Aleman, A. (2007). Impaired recognition and expression of emotional prosody in schizophrenia: Review and meta-analysis. *Clinical Psychology Review, 96,* 135–145.

Izard, C. E. (1971). *The face of emotion*. New York: Appleton-Century-Crofts.

Kaulard, K., Cunningham, D. W., Bülthoff, H. H., & Wallraven, C. (2012). The MPI Facial Expression Database—A validated database of emotional and conversational facial expressions. *PLoS ONE, 7,* e32321. doi:10.1371/journal.pone.0032321

Kerr, S. L., & Neale, J. M. (1993). Emotion perception in schizophrenia-specific deficit or further evidence of generalized poor performance. *Journal of Abnormal Psychology, 102,* 312–318.

Leentjens, A., Wielaert, S., van Harskamp, F., & Wilmink, F. (1998). Disturbances of affective prosody in patients with schizophrenia: A cross sectional study. *Journal of Neurology, Neurosurgery and Psychiatry, 64,* 375–378.

Matsumoto, D., & Ekman, P. (1988). *Japanese and Caucasian Facial Expressions of Emotion (JACFEE) and Neutral Focus (JACNeuF) [Slides]*. San Francisco: Department of Psychology, San Francisco State University.

Mazurski, E. J., & Bond, N. W. (1993). A new series of slides depicting facial expressions of affect: A comparison with the pictures of facial affect series. *Australian Journal of Psychology, 45,* 41–47.

McCann, J., & Peppe, S. (2003). Prosody in autism spectrum disorders: A critical review. *International Journal of Language and Communication Disorders, 38,* 325–350.

Morris, J. S., deBonis, M., & Dolan, R. J. (2002). Human amygdala responses to fearful eyes. *NeuroImage, 17,* 214–222.

Mower, E., Mataric, M. J., & Narayanan, S. (2009). Human perception of audio–visual synthetic character emotion expression in the presence of ambiguous and conflicting information. *IEEE Transactions on Multimedia, 11,* 843–855.

Reise, S. P., & Waller, N. G. (2009). Item response theory and clinical measurement. *Annual Review of Clinical Psychology, 5,* 27–48.

Russ, J. B., Gur, R. C., & Bilker, W. B. (2008). Validation of affective and neutral sentence content for prosodic testing. *Behavior Research Methods, 40,* 935–939. doi:10.3758/BRM.40.4.935

Savla, G. N., Vella, L., Armstrong, C. C., Penn, D. L., & Twamley, E. W. (2012). Deficits in domains of social cognition in schizophrenia: A meta-analysis of the empirical evidence. *Schizophrenia Bulletin, 39,* 979–992. doi:10.1093/schbul/sbs080

Simon, D., Craig, K. D., Gosselin, F., Belin, P., & Rainville, P. (2008). Recognition and discrimination of prototypical dynamic expressions of pain and emotions. *Pain, 1–2,* 55–64.

Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2003). Distinct spatial frequency sensitivities for processing faces and emotional expressions. *Nature Neuroscience, 6,* 624–631. doi:10.1038/nn1057

Whalen, P. J., Kagan, J., Cook, R. G., Davis, F. C., Kim, H., Polis, S., & Johnstone, T. (2004). Human amygdala responsivity to masked fearful eye whites. *Science, 306,* 2061. doi:10.1126/science.1103617

Williams, M. A., Morris, A. P., McGlone, F., Abbott, D. F., & Mattingley, J. B. (2004). Amygdala responses to fearful and happy facial expressions under conditions of binocular suppression. *Journal of Neuroscience, 24,* 2898–2904.

Winston, J. S., Vuilleumier, P., & Dolan, R. J. (2003). Effects of low-spatial frequency components of fearful faces on fusiform cortex activity. *Current Biology, 13,* 1824–1829.