Consciousness and Cognition 22 (2013) 975–986

Contents lists available at SciVerse ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Relationships between non-pathological dream-enactment and mirror behaviors ☆

Tore Nielsen [a,b,*], Don Kuiken [c]

[a] Dept. Psychiatry, Université de Montréal, Montréal, Québec, Canada
[b] Center for Advanced Research in Sleep Medicine, Hôpital du Sacré-Coeur de Montréal, Montréal, Québec, Canada
[c] Dept. Psychology, University of Alberta, Edmonton, Alberta, Canada

ARTICLE INFO

Article history:
Received 19 December 2012
Available online 19 July 2013

Keywords:
Dreaming
Dream-enacting behaviors
Mirror behaviors
Mentalizing network
Mirror neuron system
Empathy
Motor-affective resonance
Sex differences

ABSTRACT

Dream-enacting behaviors (DEBs) are behavioral expressions of forceful dream images often occurring during sleep-to-wakefulness transitions. We propose that DEBs reflect brain activity underlying social cognition, in particular, motor-affective resonance generated by the mirror neuron system. We developed a Mirror Behavior Questionnaire (MBQ) to assess some dimensions of mirror behaviors and investigated relationships between MBQ scores and DEBs in a large of university undergraduate cohort. MBQ scores were normally distributed and described by a four-factor structure (*Empathy/Emotional Contagion*, *Behavioral Imitation*, *Sleepiness/Anger Contagion*, *Motor Skill Imitation*). DEB scores correlated positively with MBQ total and factor scores even with social desirability, somnambulism and somniloquy controlled. Emotion-specific DEB items correlated with corresponding emotion-specific MBQ items, especially crying and smiling. Results provide preliminary evidence for cross-state relationships between propensities for dream-enacting and mirror behaviors—especially behaviors involving motor-affective resonance—and our suggestion that motor-affective resonance mediates dream-enactment imagery during sleep and emotional empathy during waking.

1. Introduction

Dream-enacting behaviors (DEBs), or acting out of the fictive movements, speech or emotions of a dream, are prevalent among normal college students (Nielsen, Svob, & Kuiken, 2009). Although most young adults experience them occasionally, frequent and intense DEBs are symptomatic of REM sleep behavior disorder (RBD) (Schenck, Bundlie, Ettinger, & Mahowald, 1986), sleep walking and sleep terrors (Oudiette, Leu, et al., 2009), and other nocturnal anomalies (Ohayon & Schenck, 2010) such as sleep-related eating disorders (Brion et al., 2012) and obstructive sleep apnea (Iranzo & Santamaria, 2005). One hypothesis is that DEBs occur during dreams that are of sufficient perceptual, dramatic, and emotional intensity to over-ride the neuromuscular inhibition of REM sleep. A second (and compatible) hypothesis is that DEBs result from direct disruption

Abbreviations: DEBs, dream-enacting behaviors; MBQ, Mirror Behavior Questionnaire; RBD, REM sleep behavior disorder; ToM, theory-of-mind; IFG, inferior frontal gyrus; REM, rapid eye movement; MRI, magnetic resonance imaging; EEG, electroencephalogram; DEBS, dream-enacting behavior scale; SDS, social desirability scale; EMG, electromyogram.

☆ The study was conducted at the Department of psychology of the University of Alberta, Edmonton, Alberta, Canada and the Dream & Nightmare Laboratory, Center for Advanced Research in Sleep Medicine, Hopital du Sacre-Coeur, Montreal, Quebec, Canada.

* Corresponding author. Address: Dream & Nightmare Laboratory, Hôpital du Sacré-Coeur du Montréal, 5400 boul. Gouin Ouest, Montréal, Québec H4J 1C5, Canada. Fax: +1 514 338 2531.

E-mail address: tore.nielsen@umontreal.ca (T. Nielsen).

1053-8100/$ - see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.concog.2013.06.005

of the brainstem mechanisms that maintain the atonia of REM sleep. Either dream intensity, atonia disruption, or their combination may explain how the action tendencies embodied in the fictive portrayal of a dreamer's actions result in overt behaviors that are isomorphic with the actions of the dreamed self. Consistent with this model, among RBD patients, violent actions by the dreamed self frequently culminate in overtly aggressive outbursts that may even injure the patient or his/her sleeping partner (Schenck, Lee, Bornemann, & Mahowald, 2009). Similarly, among healthy subjects, DEBs isomorphic with actions of the dreamed self are evident during nightmares but also during very sad, angry or mirthful dreams—and even intensely erotic ones (Nielsen et al., 2009).

However, the isomorphism between DEBs and fictive actions of the dreamed self may be the most salient aspect of an even more inclusive isomorphism. Some evidence suggests not only isomorphism between DEBs and actions of the dreamed self but also between DEBs and actions of other dream figures. For example, although the DEBs of RBD patients are consistently isomorphic with the aggressive actions of the dreamed self, they are regularly isomorphic with the actions of other dream figures as well. That is, their defensive—and enacted—aggression mirrors the aggression perpetrated by other dream figures (Iranzo & Santamaria, 2005; Nielsen, 2011; Schenck & Mahowald, 2002). Similarly, the DEBs of healthy subjects are regularly isomorphic with the actions of the dreamed self, but they are also occasionally isomorphic with the actions of other dream figures. For example, one laboratory subject reported that her dream enactive utterance coincided with the verbalizations of another dream character struggling aggressively to control a horse (Nielsen, McGregor, Zadra, Ilnicki, & Ouellet, 1993).

The preceding examples involve the aggression that is especially common in REM dreams (McNamara, McLaren, Smith, Brown, & Stickgold, 2005), but DEBs do not only involve aggression. RBD patients regularly report violent behaviors but also some nonviolent behaviors that are isomorphic with their own dreamed actions, such as digging up dreamed treasure or giving bossy commands (Oudiette, de Cock, et al., 2009). Similarly, NREM somnambulism and sleep terrors involve not only isomorphic aggressive actions (e.g., fighting in self-defence), but also isomorphic avoidant behaviors (e.g., screaming in fear) and expressions of emotion that are independent of fight or flight (e.g., singing dirty or childish songs) (Oudiette, Leu, et al., 2009). In these cases, too, isomorphism between DEBs and the actions of a dreamed self are complemented by occasional isomorphism between DEBs and the actions of other dream characters. For example, the dreamer may enact the growling of a feline dream figure (Eiser & Schenck, 2005); the dreamer's gestures (pointing fingers, flailing arms) may be synchronized with another character's speech (Oudiette, de Cock, et al., 2009); or the dreamer may enact another's physical assault while dreaming about actively protecting the victim (Schenck & Mahowald, 2002). Thus, dreams with DEBs are regularly isomorphic with the actions of the dreamed self, but they are also sometimes isomorphic with the actions of other dream characters.

Extension of the DEB isomorphism to include the actions of figures other than the dreamed self is consistent with evidence that sometimes the fictive actions of a dreamed other correspond with the site of somatosensory stimulation administered during REM sleep. For example, Koulack (1969) found that electrical stimulation applied to the wrist during REM sleep influenced not only the actions of the dreamed self but sometimes also the actions of other dreamed characters. Similarly, Nielsen et al. (1993) found that application of pressure stimulation to the legs during REM sleep sometimes influenced the leg sensations and actions of other characters (see dream reports in Table 2). These experimental findings suggest that covert action tendencies resulting from bodily stimulation, like overt DEBs, are isomorphic not only with actions of the dreamed self but also with the actions of other dreamed figures.

This more broadly construed isomorphism is reminiscent of the now compelling evidence that similar cortical areas (the *mirror neuron system*) are activated when a specific action (e.g., grasping something) is executed, when that action is observed, when that action is imagined for oneself (Filimon, Nelson, Hagler, & Sereno, 2007), and when it is imagined for another (Saygin, McCullough, Alac, & Emmorey, 2010; Zwaan, Taylor, & de Boer, 2010). Perhaps the isomorphism between DEBs, the actions of the dreamed self, and the actions of dreamed others depends upon the same motor-affective resonance that mediates personal and interpersonal perception and imagination during waking. The present study examines the correlation between the isomorphism that shapes DEBs and the isomorphism that shapes waking mirror behaviors (e.g., motor mimicry, empathy).

Neurophysiological factors responsible for an individual's propensity to resonate with the emotions and actions of other characters during dreaming remain unclear, but they may depend upon neural networks that underlie basic social cognition. Two anatomically distinct networks subserving social cognition include the *mentalizing network* and the *mirror neuron system*. The mentalizing network supports theory-of-mind (ToM) functions, i.e., the generic ability to recognize and explain mental states (emotions, beliefs, motives) of others (Premack & Woodruff, 1978), including the mental states of fictional others, such as characters in literary texts (Mar & Oatley, 2008). Brain imaging has revealed a consistent ensemble of regions that comprise the mentalizing network: the medial prefrontal cortex, posterior cingulate/precuneus, and bilateral temporal junction. Functioning of the mentalizing network has been explored in dream content, specifically, in the mental features that are attributed to other dreamed characters (Kahn & Hobson, 2005; Kahn, Pace-Schott, & Hobson, 2002; Schweickert & Xi, 2010). An early general assessment of dream character attributes (Kahn et al., 2002), as well as a more focused study of ToM (Kahn & Hobson, 2005), found that participants are frequently aware of what they and other dream characters are feeling in the dream. The dreamer is also frequently interested in other characters' feelings about him/herself. One study found ToM attributions to be stable in dreams, tending to be maintained once characters are introduced into the narrative—even in the face of character metamorphoses (Schweickert & Xi, 2010).

Recent two-level ToM theories (e.g., Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003; Spunt & Lieberman, 2012) stipulate that the mentalizing network depends upon activity in the more basic *mirror neuron system*. The latter becomes active both during observation of an action and performance of that action (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Rizzolatti & Craighero, 2004) and has been linked to a neural circuit that includes the posterior inferior frontal gyrus (IFG), premotor cortex, and inferior parietal lobe (see Molenberghs, Cunnington, & Mattingley, 2012 for review). Involvement of the mirror neuron system in the orchestration of self- and other-character imagery during dreaming has been proposed (Nielsen, 2007). Such involvement could explain some peculiarities of dream imagery, including the results of the somatosensory stimulation studies just mentioned (Koulack, 1969; Nielsen et al., 1993). Such involvement may also explain the interplay between body image and "felt presence" in sleep paralysis episodes, as well as in other hallucinatory events that involve the fusion of a sense of self and a sense of an other (Nielsen, 2007).

According to two-level theories of mentalization, the mirror neuron system is essential for the early stage, preconceptual identification of emotions. Thus, it may mediate affective resonance ("emotion contagion"), including contagious crying (Geangu, Benga, Stahl, & Striano, 2010), laughing (Sherman, 1975), fear (Zhou & Chen, 2009), anxiety (Eilam, Izhar, & Mort, 2011), and sadness (Papousek, Schulter, & Lang, 2009), but possibly also simple contagious yawning (Cooper, Puzzo, & Pawley, 2008). The mirror neuron system may also underlie basic emotional empathy (Schulte-Ruther, Markowitsch, Fink, & Piefke, 2007). Preconceptual emotion identification involving the mirror neuron system (e.g., the identification of anger) may enable higher-level explanation of the identified emotion through the mentalizing network (e.g., a causal explanation for anger). Functional MRI has revealed components of the mirror neuron system—the right posterior IFG in particular—that become functionally connected with the mentalization network during such higher-level attributions (Spunt & Lieberman, 2012).

The right IFG (rIFG) is one component of the mirror system of particular interest in explaining DEBs because its activity may subserve both response inhibition (Chamberlain & Sahakian, 2007) and the development of separate representations of self and other (Spengler, von Cramon, & Brass, 2010). Reduced activity in the rIFG, during overall activation of the mirror system, may explain the release from REM atonia that produces DEBs and the permeable boundaries (isomorphisms) between self and other in the dreams that accompany DEBs. It is noteworthy that rIFG activity is not decreased during normal REM sleep (Braun et al., 1998) when most vivid dreaming with normal muscle atonia occurs and clear separation between self and other in dream characters is evident (cf. Kahn & Hobson, 2005). In summary, both non-pathological DEBs observed in the general population and the pathological DEBs of RBD may reflect the abnormal reduction of rIFG inhibitory activity during overall activation of the mirror system, leading both to a reduction in muscle atonia and to the failure to develop clearly separate representations of self and other.

The goal of this study was to examine whether the self-reported frequencies of dream-enacting and mirror behaviors during waking are related. Although a number of methods have been developed for assessing the suggested neurophysiological manifestations of mirror neuron activity (e.g., EEG mu rhythm), we could locate no validated instrument for assessing differences in a subject's general propensity for expressing different types of mirror behaviors. We therefore constructed an exploratory self-report questionnaire, the *Mirror Behavior Questionnaire* (*MBQ*; see Appendix A), to assess several contagious and imitative behaviors. We expected that, if the mirror neuron system is implicated in both DEBs and mirror behaviors, we would observe positive cross-state correlations between DEBS and MBQ scores. We expected that these correlations would be independent of a general tendency to respond to questions with socially desirable responses. Finally, since DEBs are more prevalent among females than males (Nielsen et al., 2009), we expected to see sex differences in mirror behavior scores and in their correlations with DEBs.

2. Methods

Subjects were 492 students (188 males; 292 females; 12 not specified) enrolled in a first-year University Psychology course (M_{age}: 19.1 ± 1.62 yrs; range: 17–29) and receiving partial course credit for participation. They gave informed consent and participated voluntarily; they were free to choose an alternative educational activity for course credit. There were no differences in age between the three groups (M: 19.2 ± 1.73 yrs; F: 19.0 ± 1.55 yrs; NS: 19.1 ± 0.99 yrs; $p > .42$).

All subjects completed an extensive battery of questionnaires as part of a larger research program on personality and dreaming; the specifics of the battery are published elsewhere (Nielsen et al., 2009) and only some results will be described here. Subjects entered their responses to questionnaires on standard, optically scored, answer sheets that were verified manually to remove records with incorrectly coded or out of range responses. Following participation, subjects were given a thorough written debriefing.

2.1. Questionnaire measuresmeasures

Dream-Enacting Behaviors Scale (DEBS). Dream-enacting behaviors were assessed with a 6-item self-report scale derived from the results of our previous studies of DEBs in college students (Nielsen et al., 2009); items included speaking out, crying/sobbing, smiling/laughing, bodily fear, anger/defensive behavior, and other movements that often occur during

Table 1
Mirror Behavior Questionnaire items and categories.

Item	Content	Category
MB1	When you see someone else crying, are you likely to start crying as well?	Emotional contagion
MB2	When you see someone else yawning, are you likely to start yawning yourself?	Sleep contagion
MB3	When you see someone else sleeping or falling asleep are you likely to feel sleepy yourself?	Sleep contagion
MB4	When you see someone expressing anger, are you likely to feel anger yourself?	Emotional contagion
MB5	If someone smiles directly at you, are you likely to smile, too?	Emotional contagion
MB6	If you see someone smiling at someone else, are you likely to smile, too?	Emotional contagion
MB7	Do you laugh out loud when you see someone else laughing?	Emotional contagion
MB8	When you see another person's terrified face, do you feel fear, too?	Emotional contagion
MB9	When you are interacting with another person, do you tend to copy their body posture, e.g., folded arms, hands on hips, crossed legs, etc.?	Communicative imitation
MB10	When you are interacting with another person, do you tend to copy their body movements, e.g., gesturing with your face or hands, dramatizing by moving around, etc.?	Communicative imitation
MB11	When you are interacting with another person who has noticeable 'nervous motor tics' (e.g., playing with their hair, rubbing their nose, tapping their foot or fingers, pulling at their clothes), do you start to imitate some of these tics yourself?	Communicative imitation
MB12	When you are speaking with someone who has a noticeable accent or dialect, do you tend to imitate features of this accent or dialect?	Communicative imitation
MB13[a]	When you are interacting with someone who has noticeable 'verbal tics' (e.g., 'like,' 'I mean,' 'actually,' 'you know,' etc.) or pauses and hesitations (e.g., 'um,' 'er,' 'ah'), do you start using some of these features in your own speech?	Communicative imitation
MB14	Do you enjoy imitating the voices of famous people or cartoon characters?	Communicative imitation
MB15[a]	When you find yourself together with a young child who is playing a fantasy game, do you join in and play the game with him/her?	Communicative imitation
MB16	Are you a 'physically active' spectator, i.e., when watching a favorite activity or sport do you get physically involved by copying movements that you see (or would like to see)?	Communicative imitation
MB17	I easily learn a new action or skill (e.g., dance style, sports technique, use of a tool) simply by watching someone else performing it	Imitative learning
MB18	I experience a lot of empathy towards others, i.e., I am able to feel more or less what they are feeling	Empathy

[a] Item dropped as result of factor analysis.

transitions from dreaming to wakefulness. Each item was rated using a 4-point response scale (0 = never; 1 = rarely; 2 = sometimes; 3 = often). A 7th item on sexual arousal assessed by the questionnaire was excluded from this scale for several reasons. Sexual arousal as reflected in objectively measured penile tumescence is associated with dreamed anxiety (Karacan, Goodenough, Shapiro, & Starker, 1979) rather than dream eroticism. Also, item analysis revealed this item to be poorly correlated with other items (all $p > .25$); its removal from the scale was the only one to increase the scale's internal consistency (Cronbach's alpha = 0.76). A principal components analysis (Kaiser normalization, varimax rotation) of the 7 DEBs items produced a single factor (40.7% variance accounted for) on which the sexual arousal item loaded only very weakly (.382; all other items >.682). Finally, sexual arousal was the only item correlated with age ($r = .09$, $p = .04$; all other $p > .176$). Two additional items assessing somnambulism and somniloquy were also assessed to help distinguish true DEBs from these alternative forms of behavioral enactment in sleep.

2.1.1. Mirror Behavior Questionnaire (MBQ)

Mirror behaviors were assessed with an 18-item self-report scale (see Table 1). Items were selected to represent common contagious emotions (smiling, laughing), communicative mirroring (speech and motor tics, body movements), imitative learning (learning a new skill, imitating voices) and contagious sleepiness/yawning. It also included an empathy item. Each MBQ item was rated using a 4-point response scale: 0 = never; 1 = rarely; 2 = sometimes; 3 = often.

2.1.2. Social Desirability Scale (SDS)

The 13-item short-form of the Marlowe–Crowne Social Desirability Scale was administered (Crowne & Marlowe, 1960; Reynolds, 1982); it measures a form of response bias involving the presentation of self in a socially desirable (or undesirable) light. Internal consistency of the SDS is adequate, from .70 to .79 among student populations (Crino, Svoboda, Rubenfeld, & White, 1983; Tanaka-Matssumi & Kameoka, 1986); scores do not differ for men and women (Loo & Thorpe, 2000; O'Grady, 1988) and did not differ in the present study (males: 4.64 ± 2.72; females: 4.63 ± 2.88; $t_{460} = 0.032$, $p = .975$; SDS forms were incomplete for 31 subjects).

Table 2
Principal components factor analysis four-factor solution for Mirror Behavior Questionnaire items. Factors: 1 = *Empathy/Emotional Contagion*; 2 = *Behavioral Imitation*; 3 = *Sleepiness/Anger Contagion*; 4 = *Motor Skill Imitation*.

MBQ#	Item	Factors			
		1	2	3	4
18	Empathy	**0.656**	0.230	−0.169	0.047
1	Cry contagion	**0.633**	0.093	0.070	−0.111
6	Smile contagion (at other)	**0.629**	0.084	0.193	0.221
8	Fear contagion	**0.540**	0.335	0.189	−0.068
7	Laugh contagion	**0.536**	0.183	0.109	0.159
5	Smile contagion (at you)	**0.486**	−0.086	0.255	0.185
10	Copy body movements	0.237	**0.760**	0.199	0.003
9	Copy body posture	0.263	**0.720**	0.187	−0.099
11	Copy motor tics	0.082	**0.650**	0.266	0.106
12	Copy dialects	0.032	**0.582**	−0.198	0.292
3	Sleep contagion	0.136	0.135	**0.750**	−0.016
4	Anger contagion	0.032	0.172	**0.600**	0.154
2	Yawn contagion	0.388	0.069	**0.506**	−0.115
14	Imitate famous voices	−0.169	0.146	0.130	**0.689**
17	Learn new skill	0.142	−0.036	−0.108	**0.650**
16	Active spectator	0.204	0.065	0.089	**0.624**
	%Variance explained	*15.2*	*13.5*	*9.9*	*9.7*

Extraction method: principal component analysis; rotation method: Varimax with Kaiser normalization; rotation converged in 5 iterations. Coefficients in bold indicate items loading >.45 on each of the four factors.

3. Results

3.1. Dream-enacting Behaviors Scale (DEBS)

The overall mean DEBS score was 6.63 ± 3.80 with a median of 6, mode of 8, range of 0–18 (out of 18) and internal consistency (Cronbach's alpha or CA) of .672. Kurtosis of the distribution (−.283) was within the normal range of ±2SD of the SE of kurtosis (.220), i.e., −.440 to +.440. Overall, 96.7% of participants had a DEBs score >0. Females had higher DEBS scores (M = 7.20 ± 3.88; CA = .681) than did males (M = 5.80 ± 3.53; CA = .629; t_{478} = 3.99, p < .0001) and more females (98.3%) than males (94.1%) had a DEBs score > 0. DEBS scores did not correlate with social desirability (SDS scores) for the entire sample (r_{471} = −.023, p = .624) or for males (r_{178} = −.063, p = .399) or females (r_{280} = .000, p = 1.000) considered separately.

3.2. Mirror Behavior Questionnaire

The overall mean MBQ score was 24.1 ± 6.18 with a median of 24, mode of 25, and range of 7–40 (out of 48) and CA of .769. Kurtosis of the distribution (−.105) was within the normal range of ±2SD of the SE of kurtosis (.220). Females had higher MBQ scores (M = 25.2 ± 5.94) than did males (M = 22.6 ± 6.30; t_{478} = 4.53, p < .0001). MBQ scores did not correlate with SDS scores for the entire sample (r_{473} = −.064, p = .162) or for males (r_{180} = −.015, p = .840), but did so marginally and negatively for females (r_{209} = −.109, p = .068), indicating that the more females possessed a propensity to give socially desirable responses the less they tended to report mirror behaviors.

MBQ scores correlated weakly but positively with both somnambulism (r_{488} = .154, p = .001) and somniloquy (r_{482} = .151, p = .001). For males both correlations were significant (r_{186} = .146, p = .046; r_{185} = .259, p = .0004 respectively), whereas for females a correlation was found for somnambulism (r_{290} = .153, p = .009) but only marginally for somniloquy (r_{285} = .089, p = .134; Fisher-z = 1.85, p = .064 versus males). In view of these potential confounds, subsequent correlational analyses involving the DEBS partialed out both variables.

Initial principal-components analyses (IBM SPSS Statistics v19.0, 2010) with varimax rotation indicated that two MBQ items (playing with children, copying verbal tics) cross-loaded weakly on more than one factor; they were removed. Reanalysis of the 16 remaining items produced a five-factor solution (54.7% VE), two of which separated negative from positive contagious emotion items but for which the 'fear contagion' item loaded on both factors. When constrained to a four-factor solution (Table 2; 48.4% VE), the negative and positive factors and the fear contagion item combined to create a single, *Empathy/EmotionalContagion*, factor (Table 1 items MB1, MB5-MB8; 15.2% VE). The other 3 factors were the same as those from the five-factor solution; they were labeled *Behavioral Imitation* (MB9–MB12; 13.5% VE), *Sleepiness/AngerContagion* (MB2–MB4; 9.9% VE) and *Motor Skill Imitation* (MB14, MB16, MB18; 9.7% VE). The factor analyses were subsequently repeated using an oblique rotation method (oblimin) and very similar factors were obtained. Correspondingly, inter-component correlations were seen only between factors 1 and 2 (r = −.251) and factors 1 and 4 (r = .248; all others: r < .170). The four-factor varimax solution was retained and factor scores generated for use in all further analyses.

The substantial loading of *yawning* on both factors 1 and 3 was further investigated by assessing correlations between *yawning* and the 7 MBQ emotion contagion items. As shown in Table 3, all correlations were positive and significant for

Table 3
Pearson correlations between MBQ *yawning* item and all 7 MBQ emotion contagion items.

	Empathy	Crying	Anger	Smile at you	Smile at other	Laugh	Fear
Male							
r	.068	.210	.181	.132	.150	.170	.283
p	*.35683*	*.00382*	*.01300*	*.07065*	*.04010*	*.01976*	*.00009*
Female							
r	.200	.160	.146	.193	.211	.136	.246
p	*.00059*	*.00623*	*.01280*	*.00092*	*.00029*	*.01997*	*.00002*
Total							
r	.182	.279	.151	.200	.200	.153	.309
p	*.00005*	*.00000*	*.00079*	*.00002*	*.00001*	*.00066*	*.00000*

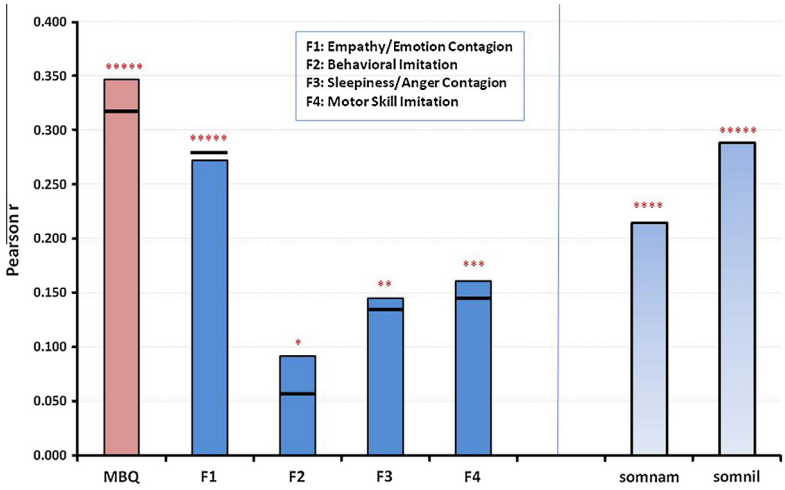

Fig. 1. Pearson correlations between DEBS, MBQ (salmon bar), MBQ factors (dark blue bars), and somnambulism and somniloquy scores (graded pale blue bars). Horizontal black segments indicate partial correlations after removal of somnambulism and somniloquy scores. $^{*****}p < .0000001$; $^{****}p < .000001$; $^{***}p < .0001$; $^{**}p < .001$; $^{*}p < .05$. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the entire sample. When considered separately by sex, this pattern of coefficients was clearly present for females, but for males the correlation between *yawning* and *empathy* was not significant.

Multivariate comparisons by sex using a one-way MANOVA with factor scores as dependent measures revealed a multivariate effect ($T_{4,472} = 43.70$, $p < .0001$) by which females scored higher than males on factor 1, *Empathy/EmotionalContagion* ($F_{1,475} = 77.43$, $p < .0001$), and males scored higher than females on factor 4, *Motor Skill Imitation* ($F_{1,475} = 51.83$, $p < .0001$). Covarying SDS did not diminish the multivariate effect ($T_{4,453} = 42.26$, $p < .0001$) or the effects for factor 1 ($F_{1,456} = 90.51$, $p < .0001$) or factor 4 ($F_{1,456} = 47.64$, $p < .0001$). Covarying somnambulism and somniloquy did not diminish the multivariate effect ($T_{4,459} = 42.04$, $p < .0001$) or the effects for factor 1 ($F_{1,462} = 87.04$, $p < .0001$) or factor 4 ($F_{1,462} = 51.80$, $p < .0001$; all other p = ns).

3.3. Global relationships between DEBS and MBQ scores

Pearson correlations between the DEBS and MBQ scores revealed moderate and highly significant, positive relationships for the entire sample ($r_{492} = .346$, $p < .0001$) and for males ($r_{188} = .405$, $p < .0001$) and females ($r_{292} = .284$, $p < .0001$) considered separately. The difference in correlations for the two sexes was not significant when tested with the Fisher *r*-to-*z* transformation ($z = 1.46$, $p = .144$, 2-tailed). The DEBS × MBQ correlations remained significant when SDS was used as a covariate (total: $r_{490} = .346$, $p < .0001$; males: $r_{177} = .405$, $p < .0001$; females: $r_{279} = .286$. $p < .0001$); they also remained significant when somnambulism and somniloquy were partialed out (total: $r_{477} = .308$, $p < .0001$; males: $r_{180} = .347$, $p < .0001$; females: $r_{281} = .251$, $p = .0003$).

For the entire sample, DEBS scores also correlated positively with each of the 4 MBQ factor scores (Fig. 1), especially factor 1, *Empathy/EmotionalContagion* ($r_{489} = .272$, $p < .0001$). For males, DEBS scores correlated with MBQ factor 1 ($r_{187} = .254$; $p = .0005$), factor 3 ($r_{187} = .256$; $p = .0004$) and factor 4 ($r_{187} = .230$; $p = .002$); for females, they correlated with MBQ factor 1 ($r_{290} = .223$; $p = .0001$) and factor 4 ($r_{290} = .245$; $p < .0001$). Partialing out SDS did not alter this profile of relationships. Also,

when somnambulism and somniloquy were used as covariates, only the correlation between DEBS and factor 2 became insignificant (r_{475} = .051; p = .270; all other p < .003; Fig. 1).

3.4. Relationships between specific DEBS and MBQ scores

To determine the specificity of relationships between dream-enacting and mirror behaviors, correlations were calculated between, on the one hand, individual DEBS items (e.g., *crying*) and all appropriate MBQ items (e.g., *smiling*, *crying*, *copy dialects*, etc.) and, conversely, individual MBQ items (e.g., *crying*) and all appropriate DEBs items (e.g., *smiling*, *fear*, *anger*, *crying*, etc.). These calculations revealed a high degree of specificity for some behaviors (see Table 3 and Fig. 2), especially *crying* (p = .003), and to a lesser extent *laughing* (p = .063) (see Table 4).

4. Discussion

Results provide support for the expected cross-state relationship between an individual's propensities for expressing dream-enacting behaviors during sleep and mirror behaviors while awake. The global nature of this relationship is reflected in the fact that total scores on both the DEBS and the MBQ were significantly correlated, that this relationship was observed for both male and female subjects, and that the relationships were largely independent of self-reported somnambulism, somniloquy and a tendency to respond in a socially desirable manner. The generality of the results was also reflected in the finding of generally elevated nonspecific correlations between various mirror behaviors and diverse DEBs. For example, the mirror behaviors of crying and laughing both correlated to some extent with general dreamed movements and other dreamed emotional behaviors. Further, factor analyses confirmed the existence of at least 4 subtypes of mirror behaviors that were associated with DEBs. The subset of mirror behaviors that was most clearly associated with dream-enacting behaviors (i.e., MBQ factor 1) included most of the positive and negative emotion contagion items and the empathy item. This grouping is not only consistent with the existence of a single affective resonance system that includes empathy, but links this system strongly with DEBs. However, the DEBS also was associated with two subsets of items that did not involve emotion (MBQ factor 3, *Behavioral Imitation*; MBQ factor 4, *Motor Skill Imitation*). This pattern is consistent with emerging views that the mirror neuron system includes a core circuit and peripheral circuits that subserve separate but interdependent motoric (e.g., movement) and non-motoric (e.g., affective) functions (Molenberghs et al., 2012). Consistent with two-level theories of mentalization, we suggest that DEBs are mediated by components of the mirror neuron system, especially

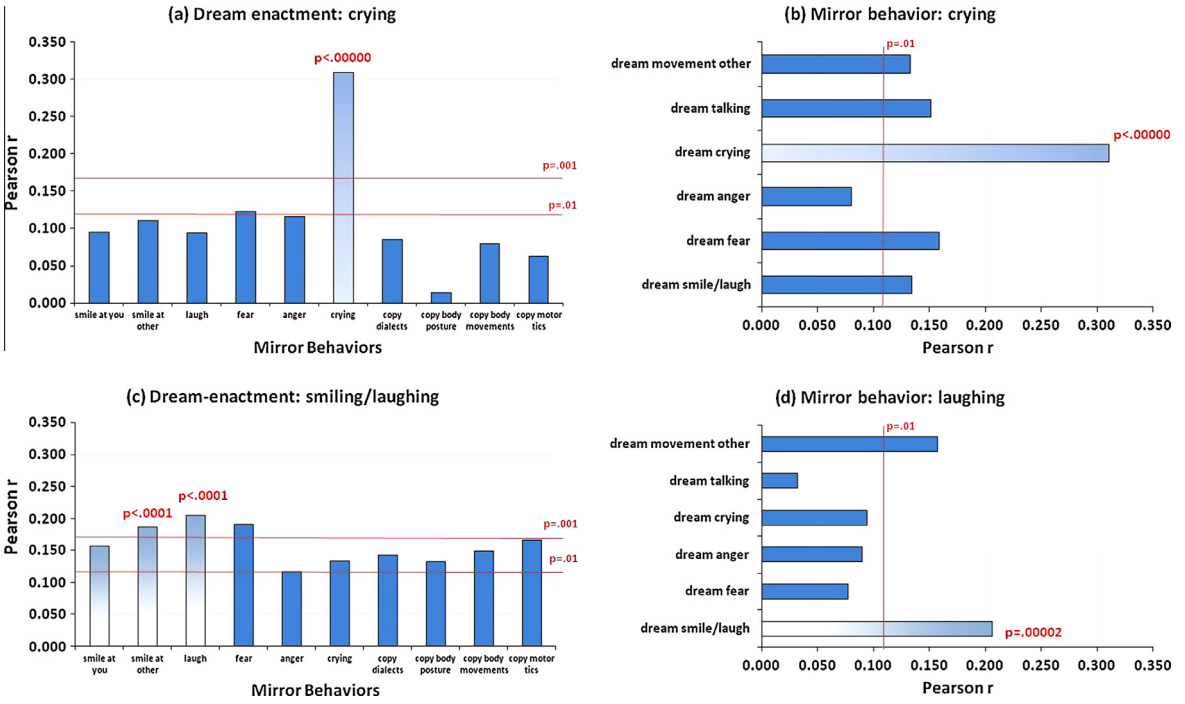

Fig. 2. Correlations between individual dream-enactment and mirror behavior items. (a) DEBS *crying* item correlates with several MBQ items but most distinctively with MBQ *crying* item (p < .000001; graded blue bar); (b) MBQ *crying* item correlates with several DEBS items but most distinctively with DEBS *crying* item (p < .000001). (c and d) Similar patterns of correlations were found for DEBS *smiling*/*laughing* and MBQ *laughing* items. Red lines indicate levels of significance for p-values of .01 and .001. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 4
Correlations between individual DEBS items and corresponding MBQ items compared with average correlations for all other MBQ items. The DEBS *crying* item correlates with the corresponding MBQ *crying* item ($r = .310$) to a significantly greater degree ($p = .003$) than it does with all other MBQ items averaged ($r = .131$).

DEBS item	Corresponding MBQ item	Ave of all other MBQ items	*Z*	*p*
Smiling	.206	.090	1.86	*.063*
Fear signs	.147	.111	0.57	*.569*
Anger	.190	.108	1.31	*.190*
Crying	.310	.131	2.95	*.003*
Talking	.093	.107	−0.22	*.926*
Other movement	.123	.092	0.49	*.624*

by the components that mediate early-stage emotional resonance, rather than by the mentalizing system that mediates later-stage emotion attribution and emotion explanation (Spunt & Lieberman, 2012).

The specificity of such early-stage emotional resonance is suggested by the relationships observed between selected DEBS and MBQ items. The emotional items *crying* and *smiling* on one questionnaire correlated distinctively with their counterparts on the other questionnaire. Thus, individuals who frequently reported crying, smiling or laughing while awakening from their dreams were also more likely to report crying, smiling or laughing when observing similar behaviors by others during wakefulness. These specific correlations may reflect the fundamentally contagious nature of these two particular emotions. Contagious crying can be triggered as early as 18 h following birth (Martin & Clark, 1982), it occurs among 1- to 9-month-old boys and girls, and it does not decrease in prevalence with age (Geangu et al., 2010). Similarly, the infectious nature of laughter ('group glee') has been identified in preschool children (Sherman, 1975) and, in adults, mirror reactions to happy facial stimuli, as measured by facial EMG, occur within 500 ms, even when the stimuli are brief, subliminal or in avatar form (Rymarczyk, Biele, Grabowska, & Majczynski, 2011; Weyers, Muhlberger, Hefele, & Pauli, 2006). Thus, the contagious emotions most clearly associated with DEBs are basic, automaticized forms of emotional resonance that developmentally and cognitively precede higher-order mentalizing (e.g., emotional inference and explanation). The clear grouping of the crying, smiling, and laughing emotion items with empathy on Factor 1 of the MBQ is consistent with the notion that such resonance represents basic emotional empathy.

Some MBQ items may not have shown clear correspondences across waking and dreaming because they describe behaviors that are less distinctive than crying, smiling, or laughing (e.g., the context specific variations of "*other movement*"). Moreover, several forms of mirror waking behaviors (e.g., *imitating famous voices*, *yawning*, *learning a new skill*) simply do not have dream awakening counterparts. Beyond these methodological constraints, however, the lack of correspondence for some MBQ items may reflect important differences in the social functions of certain emotions. For example, involuntary anger contagion may incite an escalation of anger toward the interaction partner, rather than empathy (Weyers et al., 2006). And fear contagion (Rahko et al., 2010) may initiate joint attention to a potentially shared threat, rather than empathy. Because fear and anger responses to threat predominate in nightmares, while sadness is the predominant emotion in other types of distressing dreams (e.g., existential dreams (Busink & Kuiken, 1996; Kuiken, Chudleigh, & Racher, 2010); post-partum dreams (Nielsen & Paquette, 2007)), such contrasts among these forms—and functions—of emotional contagion warrant closer inspection in future studies.

In contrast to the emotion-specific patterns, it is noteworthy that yawning was uniformly correlated with all other emotion contagion items. Yawning is a highly contagious behavior that appears as early as 4 years of age (Helt, Eigsti, Snyder, & Fein, 2010) and is frequently taken both as evidence of empathy (Platek, 2010) and of activity in the mirror neuron system (Cooper et al., 2012; Schurmann et al., 2005). Our results reinforce the notion that yawning has an evolutionarily preserved social function of communicating both sleepiness and emotion (Guggisberg, Mathis, Schnider, & Hess, 2010).

4.1. Motor and emotional resonance

Although the mechanisms linking mirror and dream-enacting behaviors remain unclear, it seems likely that behaviors in both domains involve activation of a common neural network that mediates (1) the imitation of others' movements and emotional expressions during waking; (2) the imagination of an other's execution of those same movements and emotional expressions during waking; and (3) the imagined presence of characters enacting those activities and expressions during dreaming.

1. Imitative resonance with others' movements and emotional expressions during waking is evident as surface EMG activity corresponding with the limb or facial muscle movements in an other's expression of emotion; it is also evident as the vicarious activation of analogous brain areas while observing another person's actions or emotional expressions (Dimberg, Andreasson, & Thunberg, 2011; Fadiga, Craighero, & Olivier, 2005; Lundqvist, 1995; Roosink & Zijdewind, 2010).
2. Resonance in imagination is evident as the vicarious activation of analogous peripheral and brain circuits while imagining another person's actions or emotional expressions (Aoyama & Kaneko, 2011; Fourkas, Avenanti, Urgesi, & Aglioti, 2006; Fourkas, Bonavolonta, Avenanti, & Aglioti, 2008; Williams, Pearce, Loporto, Morris, & Holmes, 2012).

3. Resonance in dream imagery may be evident as vicarious movements and emotions, as indicated by facial EMG, limb twitches and activity in motoric brain centers (Gerne & Strauch, 1985; Shimizu & Inoue, 1986). However, to the extent that these phenomena reflect only the dreamer's movements and emotions or only another dream character's movements and emotions, they may not be resonance reactions *per se*. More direct evidence of motor and affective resonance is provided by laboratory studies in which stimulation during REM sleep leads to reports of imagined activity in the analogous limbs of other (non-self) dream characters (Koulack, 1969; Nielsen et al., 1993). It is also evident in research in which, when subjects are asked to rehearse statements about attaining a desired personality attribute, the wished-for attribute manifests as a feature of both dreamed characters and the dreamed self (Cartwright, 1974). It may be concretely evident in the reports of sleep paralysis episodes involving the "felt presence" of another (Nielsen, 2007). Finally, at least two brain regions of the mirror neuron system (the inferior parietal lobule, the inferior frontal gyrus) show reduced activity during wakefulness among RBD patients (Mazza et al., 2006) for whom dream-enacting behaviors are frequent and vigorous.

In sum, although the evidence is sparse, it seems increasingly likely that both dream-enacting and mirror behaviors are mediated by vicarious activation of the mirror neural network that accompanies the perception or imagination of others' movements and emotional expressions.

4.2. Empathy, sex differences and DEBs

Individuals vary in the extent to which they exhibit motor and affective resonance. The present results suggest that resonance is particularly likely among those who self-report high levels of empathy. One possibility is that this reflects a high level of familiarity with or skill in the execution of the other's behaviors. For example, corticospinal facilitations of the muscle activity of expert tennis players are larger when they mentally imagine practicing a tennis forehand stroke than when they imagine other types of movements (Fourkas et al., 2008). Similarly, motor potentials in the arm muscles of frequent ballet spectators are larger when watching ballet than when watching other types of performances (Jola, Abedian-Amiri, Kuppuswamy, Pollick, & Grosbras, 2012). A second possibility is that these individual differences reflect a capacity for basic emotional (but not necessarily cognitive) empathy. For example, compared to low empathic subjects, highly empathic subjects display more facial EMG activity in response to appropriate facial stimuli and rate such facial stimuli as more emotionally intense (Dimberg et al., 2011; Mailhot, Vachon-Presseau, Jackson, & Rainville, 2012). However, it is important to consider a third possibility: because motor mirroring and basic empathy are mediated by the same neural network, the motor skill and empathy interpretations are not mutually exclusive. For example, corticospinal facilitation produced by watching a simple motor task is highly correlated with a measure of empathy (Lepage, Tremblay, & Theoret, 2010). Similarly, corticospinal excitability is higher when observed hand movements have an emotional component (Enticott, Kennedy, Bradshaw, Rinehart, & Fitzgerald, 2011; Montagna, Cerri, Borroni, & Baldissera, 2005).

Sex differences also may be implicated in the differential expression of dream-enacting behaviors. For example, new mothers, who are preoccupied with the health and welfare of their newborns, are particularly likely to report dream-enacting behaviors (Nielsen & Paquette, 2007). The gray matter volume of the IFG component of the mirror neuron system is larger in women (Hammers et al., 2007) and correlates with self-reported empathy (Cheng et al., 2009), factors that may directly reflect an elevated capacity for resonant motoric and emotional responding. So may the finding that activity in the key rIFG region is elevated in sensitive mothers while they listen to their own infants cry (Musser, Kaiser-Laurent, & Ablow, 2012). However, such findings more likely reflect this resonance capacity only indirectly in that the rIFG, in particular, is important for inhibiting behavioral responding (Swann, 2012). That it is implicated in both controlled and automatic response inhibition (Lenartowicz, 2011) suggests it may be particularly suited for preventing resonant behaviors triggered elsewhere in the mirror neuron network. This notion is consistent with evidence of substantial rIFG functional plasticity and the suggestion that rIFG size may change to compensate for other cognitive or executive deficits (Hajek et al., 2013).

Although the overall MBQ score was higher for females than for males in the present study, females also were higher specifically on the *Empathy/EmotionalContagion* factor. Together these results are consistent with research demonstrating higher self-reported empathy among females (Baron-Cohen & Wheelwright, 2004; Eisenberg & Lennon, 1983) and objective evidence that females demonstrate greater empathy in appropriate situations than do males. This sex difference in empathy emerges in young children (Auyeung, Allison, Wheelwright, & Baron-Cohen, 2012) and increases with age (Mestre, Samper, Frias, & Tur, 2009). Objective measures indicate that women are more empathic than men in a face-to-face empathy task and display more task-relevant activation of mirror neurons (Schulte-Ruther, Markowitsch, Shah, Fink, & Piefke, 2008; Schulte-Ruther et al., 2007). Further, both short- and long-latency ERP reactions to pictures of others in pain are more closely correlated with empathy ratings among women than they are among men (Han, Fan, & Mao, 2008). Other research has confirmed sex-related neuroanatomical differences in the human mirror-neuron system (in gray matter volumes) favoring women that are strongly linked to empathy competence (Cheng et al., 2009).

It is noteworthy that DEBs were associated with somnambulism and somniloquy in our analyses. Mounting evidence that these sleep behaviors are often accompanied by vivid, emotional, dream imagery (Oudiette, Leu, et al., 2009) suggests that these NREM sleep parasomnias may constitute an alternative expression of mirror neuron activity during sleep, albeit one during which the absence of REM sleep atonia permits a more elaborate—if not dramatic—expression of the imagery. However, that our findings also demonstrate a clear independence between mirror behaviors and DEBs on the one hand

and somnambulism and somniloquy on the other supports the possibility that the mirror neuron system influences cognitive activity in similar ways throughout sleep.

In conclusion, the newly developed MBQ assesses several types of mirror behaviors during waking that are correlated with dream enacting behaviors during sleep. This generic cross-state correlation is independent of social desirability, somnambulism and somniloquy. Moreover, correlations between emotion-specific DEB items and corresponding emotion-specific MBQ items, provide evidence of cross-state relationships especially for behaviors that involve emotional resonance. These emotion-specific correspondences suggest that, rather than implicating a broader mentalizing network concerned with the attribution and explanation of others' mental states, DEBs reflect the more basic and developmentally earlier resonances mediated by the mirror neuron system. Though preliminary, the findings support our notion that motor and affective resonance mediates both the enactment of dream imagery during sleep and basic emotional empathy during waking.

Acknowledgments

The research was funded by the Canadian Institutes of Health Research (TN) and the Natural Sciences and Engineering Research Council of Canada (TN).

Appendix A. Mirror Behavior Questionnaire (MBQ)

The following questions concern reactions of yours that may be influenced by the behaviors of other people. Please rate each one on the 0–3 scale.

1. When you see someone else **crying**, are you likely to start crying as well?	Never(0)	Rarely(1)	Sometimes(2)	Often(3)
2. When you see someone else **yawning**, are you likely to start yawning yourself?	Never(0)	Rarely(1)	Sometimes(2)	Often(3)
3. When you see someone else **sleeping or falling asleep** are you likely to feel sleepy yourself?	Never(0)	Rarely(1)	Sometimes(2)	Often(3)
4. When you see someone **expressing anger**, are you likely to feel anger yourself?	Never(0)	Rarely(1)	Sometimes(2)	Often(3)
5. If someone **smiles directly at you**, are you likely to smile, too?	Never(0)	Rarely(1)	Sometimes(2)	Often(3)
6. If you see someone **smiling at someone else**, are you likely to smile, too?	Never(0)	Rarely(1)	Sometimes(2)	Often(3)
7. Do you laugh out loud when you see someone else **laughing**?	Never(0)	Rarely(1)	Sometimes(2)	Often(3)
8. When you see another person's **terrified face**, do you feel fear, too?	Never(0)	Rarely(1)	Sometimes(2)	Often(3)
9. When you are interacting with another person, do you tend to copy their **body posture**, e.g., folded arms, hands on hips, crossed legs, etc.?	Never(0)	Rarely(1)	Sometimes(2)	Often(3)
10. When you are interacting with another person, do you tend to copy their **body movements**, e.g., gesturing with your face or hands, dramatizing by moving around, etc.?	Never(0)	Rarely(1)	Sometimes(2)	Often(3)
11. When you are interacting with another person who has noticeable '**nervous motor tics**' (e.g., playing with their hair, rubbing their nose, tapping their foot or fingers, pulling at their clothes), do you start to imitate some of these tics yourself?	Never(0)	Rarely(1)	Sometimes(2)	Often(3)
12. When you are speaking with someone who has a noticeable **accent or dialect**, do you tend to imitate features of this accent or dialect?	Never(0)	Rarely(1)	Sometimes(2)	Often(3)
13. When you are interacting with someone who has noticeable '**verbal tics**' (e.g., 'like,' 'I mean,' 'actually,' 'you know,' etc.) or pauses and hesitations (e.g., 'um,' 'er,' 'ah'), do you start using some of these features in your own speech?	Never(0)	Rarely(1)	Sometimes(2)	Often(3)
14. Do you enjoy **imitating the voices of famous people or cartoon characters**?	Never(0)	Rarely(1)	Sometimes(2)	Often(3)
15. When you find yourself together with a young child who is playing a **fantasy game**, do you join in and play the game with him/her?	Never(0)	Rarely(1)	Sometimes(2)	Often(3)
16. Are you a **'physically active' spectator**, i.e., when watching a favorite activity or sport do you get physically involved by copying movements that you see (or would like to see)?	Never(0)	Rarely(1)	Sometimes(2)	Often(3)

17. I easily **learn a new action or skill** (e.g., dance style, sports technique, use of a tool) simply by watching someone else performing it	Never(0)	Rarely(1)	Sometimes(2)	Often(3)
18. I experience a lot of **empathy towards others**, i.e., I am able to feel more or less what they are feeling	Never(0)	Rarely(1)	Sometimes(2)	Often(3)

References

Aoyama, T., & Kaneko, F. (2011). The effect of motor imagery on gain modulation of the spinal reflex. *Brain Research, 1372*, 41–48.

Auyeung, B., Allison, C., Wheelwright, S., & Baron-Cohen, S. (2012). Brief report: Development of the adolescent empathy and systemizing quotients. *Journal of Autism and Developmental Disorders*.

Baron-Cohen, S., & Wheelwright, S. (2004). The empathy quotient: An investigation of adults with Asperger syndrome or high functioning autism, and normal sex differences. *Journal of Autism and Developmental Disorders, 34*, 163–175.

Braun, A. R., Balkin, T. J., Wesensten, N. J., Gwadry, F., Carson, R. E., Varga, M., et al (1998). Dissociated pattern of activity in visual cortices and their projections during human rapid eye movement sleep. *Science, 279*, 91–95.

Brion, A., Flamand, M., Oudiette, D., Voillery, D., Golmard, J. L., & Arnulf, I. (2012). Sleep-related eating disorder versus sleepwalking: A controlled study. *Sleep Medicine, 13*, 1094–1101.

Busink, R., & Kuiken, D. (1996). Identifying types of impactful dreams – A replication. *Dreaming, 6*, 97–119.

Carr, L., Iacoboni, M., Dubeau, M. C., Mazziotta, J. C., & Lenzi, G. L. (2003). Neural mechanisms of empathy in humans: A relay from neural systems for imitation to limbic areas. *Proceedings of the National Academy of Sciences of the United States of America, 100*, 5497–5502.

Cartwright, R. D. (1974). The influence of a conscious wish on dreams: A methodological study of dream meaning and function. *Journal of Abnormal Psychology, 83*, 387–393.

Chamberlain, S. R., & Sahakian, B. J. (2007). The neuropsychiatry of impulsivity. *Current Opinion in Psychiatry, 20*, 255–261.

Cheng, Y., Chou, K. H., Decety, J., Chen, I. Y., Hung, D., Tzeng, O. J., et al (2009). Sex differences in the neuroanatomy of human mirror-neuron system: A voxel-based morphometric investigation. *Neuroscience, 158*, 713–720.

Cooper, N. R., Puzzo, I., & Pawley, A. D. (2008). Contagious yawning: The mirror neuron system may be a candidate physiological mechanism. *Medical Hypotheses, 71*, 975–976.

Cooper, N. R., Puzzo, I., Pawley, A. D., Bowes-Mulligan, R. A., Kirkpatrick, E. V., Antoniou, P. A., et al (2012). Bridging a yawning chasm: EEG investigations into the debate concerning the role of the human mirror neuron system in contagious yawning. *Cognitive, Affective and Behavioral Neuroscience, 12*, 393–405.

Crino, M. D., Svoboda, M., Rubenfeld, S., & White, M. C. (1983). Data on the Marlowe–Crowne and Edwards social desirability scales. *Psychological Reports, 53*, 963–968.

Crowne, D. P., & Marlowe, D. (1960). A new scale of social desirability independent of psychopathology. *Journal of Consulting Psychology, 24*, 349–354.

di Pellegrino, G., Fadiga, L., Fogassi, L., Gallese, V., & Rizzolatti, G. (1992). Understanding motor events: A neurophysiological study. *Experimental Brain Research, 91*, 176–180.

Dimberg, U., Andreasson, P., & Thunberg, M. (2011). Emotional empathy and facial reactions to facial expressions. *Journal of Psychophysiology, 25*, 26–31.

Eilam, D., Izhar, R., & Mort, J. (2011). Threat detection: Behavioral practices in animals and humans. *Neuroscience and Biobehavioral Reviews, 35*, 999–1006.

Eisenberg, N., & Lennon, R. (1983). Sex differences in empathy and related capacities. *Psychological Bulletin, 94*, 100–131.

Eiser, A. S., & Schenck, C. H. (2005). Dreaming: A psychiatric view and insights from the study of parasomnias. *Schweizer Archiv fur Neurologie und Psychiatrie, 156*, 440–470.

Enticott, P. G., Kennedy, H. A., Bradshaw, J. L., Rinehart, N. J., & Fitzgerald, P. B. (2011). Motor corticospinal excitability during the observation of interactive hand gestures. *Brain Research Bulletin, 85*, 89–95.

Fadiga, L., Craighero, L., & Olivier, E. (2005). Human motor cortex excitability during the perception of others' action. *Current Opinion in Neurobiology, 15*, 213–218.

Filimon, F., Nelson, J. D., Hagler, D. J., & Sereno, M. I. (2007). Human cortical representations for reaching: Mirror neurons for execution, observation, and imagery. *Neuroimage*.

Fourkas, A. D., Avenanti, A., Urgesi, C., & Aglioti, S. M. (2006). Corticospinal facilitation during first and third person imagery. *Experimental Brain Research, 168*, 143–151.

Fourkas, A. D., Bonavolonta, V., Avenanti, A., & Aglioti, S. M. (2008). Kinesthetic imagery and tool-specific modulation of corticospinal representations in expert tennis players. *Cerebral Cortex, 18*, 2382–2390.

Geangu, E., Benga, O., Stahl, D., & Striano, T. (2010). Contagious crying beyond the first days of life. *Infant Behavior and Development, 33*, 279–288.

Gerne, M., & Strauch, I. (1985). Psychophysiological indicators of affect patterns and conversational signals during sleep. In W. P. Koella, E. Ruther, & H. Schulz (Eds.), *Sleep '84* (pp. 367–369). Stuttgart: Gustav Fischer Verlag.

Guggisberg, A. G., Mathis, J., Schnider, A., & Hess, C. W. (2010). Why do we yawn? *Neuroscience and Biobehavioral Reviews, 34*, 1267–1276.

Hajek, T., Cullis, J., Novak, T., Kopecek, M., Blagdon, R., Propper, L., et al (2013). Brain structural signature of familial predisposition for bipolar disorder: Replicable evidence for involvement of the right inferior frontal gyrus. *Biological Psychiatry, 73*, 144–152.

Hammers, A., Chen, C. H., Lemieux, L., Allom, R., Vossos, S., Free, S. L., et al (2007). Statistical neuroanatomy of the human inferior frontal gyrus and probabilistic atlas in a standard stereotaxic space. *Human Brain Mapping, 28*, 34–48.

Han, S., Fan, Y., & Mao, L. (2008). Gender difference in empathy for pain: An electrophysiological investigation. *Brain Research, 1196*, 85–93.

Helt, M. S., Eigsti, I. M., Snyder, P. J., & Fein, D. A. (2010). Contagious yawning in autistic and typical development. *Child Development, 81*, 1620–1631.

Iranzo, A., & Santamaria, J. (2005). Severe obstructive sleep apnea/hypopnea mimicking REM sleep behavior disorder. *Sleep, 28*, 203–206.

Jola, C., Abedian-Amiri, A., Kuppuswamy, A., Pollick, F. E., & Grosbras, M. H. (2012). Motor simulation without motor expertise: Enhanced corticospinal excitability in visually experienced dance spectators. *PLoS ONE, 7*, e33343.

Kahn, D., & Hobson, J. A. (2005). Theory of mind and dreaming: Awareness of feelings and thoughts of others in dreams. *Dreaming, 15*, 48–57.

Kahn, D., Pace-Schott, E., & Hobson, J. A. (2002). Emotion and cognition: Feeling and character identification in dreaming. *Consciousness and Cognition, 11*, 34–50.

Karacan, I., Goodenough, D. R., Shapiro, A., & Starker, S. (1979). Erection cycle during sleep in relation to dream anxiety. In L. A. Gottschalk (Ed.), *The content analysis of verbal behavior* (pp. 887–893). New York: Spectrum Pub..

Koulack, D. (1969). Effects of somatosensory stimulation on dream content. *Archives of General Psychiatry, 20*, 718–725.

Kuiken, D., Chudleigh, M., & Racher, D. (2010). Bilateral eye movements, attentional flexibility and metaphor comprehension: The substrate of REM dreaming? *Dreaming, 20*, 227–247.

Lenartowicz, A., Verbruggen, F., Logan, G. D., & Poldrack, R. A. (2011). Inhibition-related activation in the right inferior frontal gyrus in the absence of inhibitory cues. *Journal of Cognitive Neuroscience, 23*, 3388–3399.

Lepage, J. F., Tremblay, S., & Theoret, H. (2010). Early non-specific modulation of corticospinal excitability during action observation. *European Journal of Neuroscience, 31*, 931–937.

Loo, R., & Thorpe, K. (2000). Confirmatory factor analyses of the full and short versions of the Marlowe–Crowne Social Desirability Scale. *Journal of Social Psychology, 140*, 628–635.

Lundqvist, L. O. (1995). Facial EMG reactions to facial expressions: A case of facial emotional contagion? *Scandinavian Journal of Psychology, 36*, 130–141.
Mailhot, J. P., Vachon-Presseau, E., Jackson, P. L., & Rainville, P. (2012). Dispositional empathy modulates vicarious effects of dynamic pain expressions on spinal nociception, facial responses and acute pain. *European Journal of Neuroscience, 35*, 271–278.
Mar, R. A., & Oatley, K. (2008). The function of fiction is the abstraction and simulation of social experience. *Perspectives in Psychological Science, 3*, 173–192.
Martin, G. B., & Clark, R. D. (1982). Distress crying in neonates: Species and peer specificity. *Developmental Psychology, 18*, 3–9.
Mazza, S., Soucy, J. P., Gravel, P., Michaud, M., Postuma, R., Massicotte-Marquez, J., et al (2006). Assessing whole brain perfusion changes in patients with REM sleep behavior disorder. *Neurology, 67*, 1618–1622.
McNamara, P., McLaren, D., Smith, D., Brown, A., & Stickgold, R. (2005). A ''Jekyll and Hyde'' within: Aggressive versus friendly interactions in REM and non-REM dreams. *Psychological Science, 16*, 130–136.
Mestre, M. V., Samper, P., Frias, M. D., & Tur, A. M. (2009). Are women more empathetic than men? A longitudinal study in adolescence. *Spanish Journal of Psychology, 12*, 76–83.
Molenberghs, P., Cunnington, R., & Mattingley, J. B. (2012). Brain regions with mirror properties: A meta-analysis of 125 human fMRI studies. *Neuroscience and Biobehavioral Reviews, 36*, 341–349.
Montagna, M., Cerri, G., Borroni, P., & Baldissera, F. (2005). Excitability changes in human corticospinal projections to muscles moving hand and fingers while viewing a reaching and grasping action. *European Journal of Neuroscience, 22*, 1513–1520.
Musser, E. D., Kaiser-Laurent, H., & Ablow, J. C. (2012). The neural correlates of maternal sensitivity: An fMRI study. *Developmental Cognitive Neuroscience, 2*, 428–436.
Nielsen, T. A. (2007). Felt presence: Paranoid delusion or hallucinatory social imagery? *Consciousness and Cognition, 16*, 975–983.
Nielsen, T. (2011). Disturbed dreaming as a factor in medical conditions. In M. Kryger, T. Roth, & W. C. Dement (Eds.), *Principles and practice of sleep medicine* (5th ed., pp. 1116–1127). New York: Elsevier.
Nielsen, T. A., McGregor, D. L., Zadra, A., Ilnicki, D., & Ouellet, L. (1993). Pain in dreams. *Sleep, 16*, 490–498.
Nielsen, T., & Paquette, T. (2007). Dream-associated behaviors affecting pregnant and postpartum women. *Sleep, 30*, 1162–1169.
Nielsen, T., Svob, C., & Kuiken, D. (2009). Dream-enacting behaviors in a normal population. *Sleep, 32*, 1629–1636.
O'Grady, K. E. (1988). The Marlowe–Crowne and Edwards social desirability scales: A psychometric perspective. *Multivariate Behavioral Research, 23*, 87–101.
Ohayon, M. M., & Schenck, C. H. (2010). Violent behavior during sleep: Prevalence, comorbidity and consequences. *Sleep Medicine, 11*, 941–946.
Oudiette, D., de Cock, V. C., Lavault, S., Leu, S., Vidailhet, M., & Arnulf, I. (2009). Nonviolent elaborate behaviors may also occur in REM sleep behavior disorder. *Neurology, 72*, 551–557.
Oudiette, D., Leu, S., Pottier, M., Buzare, M. A., Brion, A., & Arnulf, I. (2009). Dreamlike mentations during sleepwalking and sleep terrors in adults. *Sleep, 32*, 1621–1627.
Papousek, I., Schulter, G., & Lang, B. (2009). Effects of emotionally contagious films on changes in hemisphere-specific cognitive performance. *Emotion, 9*, 510–519.
Platek, S. M. (2010). Yawn, yawn, yawn, yawn; yawn, yawn, yawn! The social, evolutionary and neuroscientific facets of contagious yawning. *Frontiers of Neurology and Neuroscience, 28*, 107–112.
Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences, 4*, 515–526.
Rahko, J., Paakki, J. J., Starck, T., Nikkinen, J., Remes, J., Hurtig, T., et al (2010). Functional mapping of dynamic happy and fearful facial expression processing in adolescents. *Brain Imaging and Behaviour, 4*, 164–176.
Reynolds, W. M. (1982). Development of reliable and valid short forms of the Marlowe–Crowne Social Desirability Scale. *Journal of Clinical Psychology, 38*, 119–125.
Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience, 27*, 169–192.
Roosink, M., & Zijdewind, I. (2010). Corticospinal excitability during observation and imagery of simple and complex hand tasks: Implications for motor rehabilitation. *Behavioral Brain Research, 213*, 35–41.
Rymarczyk, K., Biele, C., Grabowska, A., & Majczynski, H. (2011). EMG activity in response to static and dynamic facial expressions. *International Journal of Psychophysiology, 79*, 330–333.
Saygin, A. P., McCullough, S., Alac, M., & Emmorey, K. (2010). Modulation of BOLD response in motion-sensitive lateral temporal cortex by real and fictive motion sentences. *Journal of Cognitive Neuroscience, 22*, 2480–2490.
Schenck, C. H., Bundlie, S. R., Ettinger, M. G., & Mahowald, M. W. (1986). Chronic behavioral disorders of human REM sleep: A new category of parasomnia. *Sleep, 9*, 293–308.
Schenck, C. H., Lee, S. A., Bornemann, M. A., & Mahowald, M. W. (2009). Potentially lethal behaviors associated with rapid eye movement sleep behavior disorder: Review of the literature and forensic implications. *Journal of Forensic Sciences, 54*, 1475–1484.
Schenck, C. H., & Mahowald, M. W. (2002). REM sleep behavior disorder: Clinical, developmental, and neuroscience perspectives 16 years after its formal identification in SLEEP. *Sleep, 25*, 120–138.
Schulte-Ruther, M., Markowitsch, H. J., Fink, G. R., & Piefke, M. (2007). Mirror neuron and theory of mind mechanisms involved in face-to-face interactions: A functional magnetic resonance imaging approach to empathy. *Journal of Cognitive Neuroscience, 19*, 1354–1372.
Schulte-Ruther, M., Markowitsch, H. J., Shah, N. J., Fink, G. R., & Piefke, M. (2008). Gender differences in brain networks supporting empathy. *Neuroimage, 42*, 393–403.
Schurmann, M., Hesse, M. D., Stephan, K. E., Saarela, M., Zilles, K., Hari, R., et al (2005). Yearning to yawn: The neural basis of contagious yawning. *Neuroimage, 24*, 1260–1264.
Schweickert, R., & Xi, Z. (2010). Metamorphosed characters in dreams: Constraints of conceptual structure and amount of theory of mind. *Cognitive Science, 34*, 665–684.
Sherman, L. W. (1975). An ecological study of glee in small groups of preschool children. *Child Development, 46*, 53–61.
Shimizu, A., & Inoue, T. (1986). Dreamed speech and speech muscle activity. *Psychophysiology, 23*, 210–214.
Spengler, S., von Cramon, D. Y., & Brass, M. (2010). Resisting motor mimicry: control of imitation involves processes central to social cognition in patients with frontal and temporo-parietal lesions. *Social Neuroscience, 5*, 401–416.
Spunt, R. P., & Lieberman, M. D. (2012). An integrative model of the neural systems supporting the comprehension of observed emotional behavior. *Neuroimage, 59*, 3050–3059.
Swann, N. C., Cai, W., Conner, C. R., Pieters, T. A., Claffey, M. P., George, J. S., Aron, A. R., & Tandon, N. (2012). Roles for the pre-supplementary motor area and the right inferior frontal gyrus in stopping action: electrophysiological responses and functional and structural connectivity. *Neuroimage, 59*, 2860–2870.
Tanaka-Matssumi, J., & Kameoka, V. A. (1986). Reliabilities and concurrent validities of popular self-report measures of depression, anxiety, and social desirability. *Journal of Consulting and Clinical Psychology, 54*, 328–333.
Weyers, P., Muhlberger, A., Hefele, C., & Pauli, P. (2006). Electromyographic responses to static and dynamic avatar emotional facial expressions. *Psychophysiology, 43*, 450–453.
Williams, J., Pearce, A. J., Loporto, M., Morris, T., & Holmes, P. S. (2012). The relationship between corticospinal excitability during motor imagery and motor imagery ability. *Behavioral Brain Research, 226*, 369–375.
Zhou, W., & Chen, D. (2009). Sociochemosensory and emotional functions: Behavioral evidence for shared mechanisms. *Psychological Science, 20*, 1118–1124.
Zwaan, R. A., Taylor, L. J., & de Boer, M. (2010). Motor resonance as a function of narrative time: Further tests of the linguistic focus hypothesis. *Brain and Language, 112*, 143–149.