

Why Introverts Can't Always Tell Who Likes Them: Multitasking and Nonverbal Decoding

Matthew D. Lieberman and Robert Rosenthal
Harvard University

Despite personality theories suggesting that extraversion correlates with social skill, most studies have not found a positive correlation between extraversion and nonverbal decoding. The authors propose that introverts are less able to multitask and thus are poorer at nonverbal decoding, but only when it is a secondary task. Prior research has uniformly extracted the nonverbal decoding from its multitasking context and, consequently, never tested this hypothesis. In Studies 1–3, introverts exhibited a nonverbal decoding deficit, relative to extraverts, but only when decoding was a secondary rather than a primary task within a multitasking context. In Study 4, extraversion was found to correlate with central executive efficiency ($r = .42$) but not with storage capacity ($r = .04$). These results are discussed in terms of arousal theories of extraversion and the role of catecholamines (dopamine and norepinephrine) in prefrontal function.

The ability to interact effectively in social environments is essential to success in everyday life. Indeed, there is an ongoing debate in our school systems about whether our public schools should attempt to improve the emotional and social intelligence of children (Cantor & Kihlstrom, 1985; Mayer & Salovey, 1997; Sternberg, 1985). Goleman (1995) has described emotionally intelligent individuals as “keenly attuned to the ways others are reacting, and so are able to continually fine-tune their social performance, adjusting it to make sure they are having the desired effect” (p. 119). To the research psychologist, this description sounds suspiciously like a description of the personality complex known as *extraversion*. Specifically, a number of theoretical frameworks suggest that extraverts are more socially skilled than introverts, in part because they are better decoders of nonverbal communication (Allport, 1924; Eysenck, 1967, 1990; Jung, 1923/1971; Sapir, 1958). Our common sense suggests that this should be

the case as extraversion is equated in the popular mind with social ease and success in social interactions (Argyle & Lu, 1990a, 1990b). Given that a large part of social communication is nonverbal, extraverts are prime candidates to be superior nonverbal decoders. Consequently, it is rather surprising that most research attempting to find this extravert decoding advantage has come up empty-handed. The majority of studies have shown no correlation between extraversion and nonverbal decoding ability or have shown a correlation favoring introverts as better decoders (Cunningham, 1977; Hecht, 1995; Riggio & Friedman, 1982; Rosenthal, Hall, DiMatteo, Rogers, & Archer, 1979; Vingoe & Antonoff, 1968).

Why have the majority of researchers not found this individual difference when most theories and experimental hypotheses predict that extraverts will outshine introverts in the arena of nonverbal decoding? We propose that the important correlate of extraversion is working-memory efficiency rather than nonverbal decoding ability per se. More efficient working-memory processes would translate into more effective *multitasking*, the process of pursuing multiple goals simultaneously rather than sequentially. People often have multiple social goals when interacting, and if extraverts are indeed more capable of maintaining and carrying out multiple goals simultaneously, then this might give rise to the perception that they are better nonverbal decoders. Thus, introverts might have the same level of nonverbal decoding skill as do extraverts, but they may have greater difficulty applying that skill in multitasking contexts. Past research on nonverbal decoding usually has required that participants maintain only a single goal: accurate decoding. Such studies are not expected to show a decoding advantage for extraverts, because the nonverbal decoding occurred outside of a multitasking context. Introverts are expected to show an impairment in nonverbal decoding performance

Matthew D. Lieberman and Robert Rosenthal, Department of Psychology, Harvard University.

Robert Rosenthal is now at the Department of Psychology, University of California, Riverside.

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Correspondence concerning this article should be addressed to Matthew D. Lieberman, who is now at the Department of Psychology, Franz Hall, University of California, Los Angeles, California 90095-1563. Electronic mail may be sent to lieber@ucla.edu.

only when nonverbal decoding is engaged by a secondary goal in a multitasking context rather than by a primary goal. In short, the common intuition that extraverts are better nonverbal decoders than are introverts is based on everyday observation in a rich, complex social environment that previous research has failed to model.

The Utility of Nonverbal Cues

At least three assumptions are involved in the common belief that extraverts are better nonverbal decoders than introverts: (a) nonverbal cues are a valid source of information regarding the affective attitudes of others, (b) people actually know that nonverbal cues have this usefulness and that social competence prescribes their use, and (c) extraverts are more socially competent and thus likely to be greater beneficiaries of the wealth of relevant nonverbal cues. Each of these assumptions is, in fact, borne out by ample empirical evidence.

Nonverbal cues do reveal a good deal about our affective reactions (Archer & Akert, 1977; Ekman, Friesen, & Ellsworth, 1972; Patterson, 1995; Scherer, 1981; Swann, Stein-Seroussi, & McNulty, 1992), with some authors suggesting that nonverbal behavior is the "primary medium for the communication of affect" (Feldman, Philipponot, & Custrini, 1991 p. 332; also see Argyle, 1969; Buck, 1984; Cacioppo, Martzbe, Petty, & Tassinari, 1988). Additionally, a number of cue-opposition studies have pitted the influence of verbal and nonverbal cues against each other and have found that people rely on the nonverbal cues more than twice as much as the verbal cues in forming judgments about a target (Argyle, Alkema, & Gilmour, 1972; Bugental, Kaswan, & Love, 1970; Mehrabian & Wiener, 1967; cf. Trimboli & Walker, 1987).

The Social Competence of Extraverts

There are three theoretical frameworks at present that suggest that extraverts have greater social competence than do introverts. Although the theories agree in this conclusion, the explanations are of different kinds.

Jung (1923/1971) is responsible for bringing the extraversion-introversion dichotomy into common usage among the lay populace. Jung himself acknowledged that the personality dimension has a long history extending back through James, Schiller, Nietzsche, and others, but clearly Jung's characterization has made the deepest imprint on society. Jung suggested that the difference between the extravert and the introvert is one of attentional orientation. He suggested that for the introvert, the stimuli deemed worthy of attention are those of the introvert's own mind. For Jung's introvert, the internal reaction takes precedence over the thing reacted to, out in the world. Alternatively, Jung described the extravert as "the lover of tangible reality, with little inclination for reflection . . . To feel the object, to have sensations and if possible enjoy them—that is his constant aim" (p. 364). Furthermore, the extravert was thought to be successful in this enterprise. As Jung surmised, "If a man thinks, feels, acts, and actually lives in a way that is directly correlated with the objective conditions and their demands, he is extraverted" (p. 333). Jung considered this attention to the social domain and extraverts' need to modulate their cognitions and behaviors to fit the demands of the social world the

main reasons for extraverts' social success. Jung, an advocate for introverts, then went on to spend many pages explaining why it is misguided for the public to malign introverts for their lack of social competence.

Eysenck's (1967, 1990, 1997) approach, which has received widespread acceptance over the last three decades, investigated the biological basis of extraversion. Eysenck suggested that introverts have higher baseline levels (tonic) of cortical arousal as well as more reactivity (phasic) to individual stimuli than do extraverts, as reflected in an ascending reticular activating system that is more easily and powerfully activated. Combining this with Freud's *constancy principle* (Breuer & Freud, 1895/1937), which suggests that there is an optimal level of cortical arousal, Eysenck's rationale for extraverts' convivial tendencies becomes clear (Zuckerman, 1987). Extraverts compensate for their suboptimal arousal levels by tending toward more arousing tasks that involve greater sensory stimulation. Accordingly, greater general attention to details in the social domain should follow (Akert & Panter, 1988; Eysenck & Eysenck, 1968).

Allport (1924) and Sapir (1958) provided additional theoretical support for the social competence of extraverts with their suggestion that the learning of social, affective, and evaluative cues is a slow developmental process, obtained only with extensive experience. Allport suggested that extraverts' natural proclivity toward social interaction provides extraverts, but not introverts, with the necessary experience and practice to gain fluency with these cues.

The empirical evidence relating extraversion and social competence is limited to correlational analyses. In the construction of their Social Competence Questionnaire, Schneider, Ackerman, and Kanfer (1996) found that extraversion emerged as one of the factors of social competence. Riggio (1986) found that the Social Skills Inventory correlated strongly with the Extraversion subscale of the Self-Monitoring Scale (SMS-Extraversion; Briggs, Cheek, & Buss, 1980; Snyder, 1974). Argyle and Lu (1990a) concluded that the "happiness of extraverts" (Argyle & Lu, 1990b) is mediated by extraverts' greater social competence. Finally, Jenkins (1998) combined self-report scales with behavioral measures and found that judges rated extraverts higher on social competence in their social interactions.

Empirical Approaches to Extraversion and Nonverbal Decoding

Given the variety of theoretical threads suggesting a plausible association between extraversion and nonverbal decoding, the obvious next step would be for researchers to go out, demonstrate the relationship, claim the data with the flag of their favorite theory's homeland, and go home. Indeed, over the past 30 years a number of researchers have set out to do just this. Few, however, obtained the predicted results.

Vingoe and Antonoff (1968) examined the profile of good and bad judges of personality on the basis of their visual observations of the targets. Among the relevant characteristics, good judges were found to be more introverted than bad judges ($r = -.55, p <$

.03).¹ Extraversion was measured using the Eysenck Personality Inventory (EPI; Eysenck & Eysenck, 1968).

Cunningham (1977) had participants rate the positivity of the moods being expressed in video clips that consisted of actors' attempts to express different moods. Extraversion was measured by using the EPI, and no reliable relation was found between extraversion and accuracy on the mood-rating task ($r = -.12$, $p > .2$)

Three studies using the Profile of Nonverbal Sensitivity (PONS; Rosenthal, Hall, DiMatteo, Rogers, & Archer, 1979) as a measure of nonverbal decoding ability have also been unsuccessful in demonstrating a positive relation between extraversion and decoding ability. The PONS is composed of 220 video clips, each lasting 2 s. In each clip, a woman expresses an emotion or attitude and the participant must chose between two possible descriptions of what is being expressed (e.g., "expressing motherly love," "trying to seduce someone"). The clips consist of different displays combining face, body, and audio cues. Using the PONS, Rosenthal and colleagues (1979) found no reliable relation between extraversion, as measured by the Myers-Briggs Type Indicator (Myers, 1962), and the ability to decode any of the combinations of nonverbal information ($r = .04$, $p > .2$). Likewise, Riggio and Friedman (1982) also found no reliable correlation between extraversion, using SMS-Extraversion, and scores on the PONS test ($r = .12$, $p > .2$). Hecht (1995), in three different samples, found correlations of .00, $-.27$, and $-.27$ (combined, $r = -.19$, $p < .07$) between extraversion, based on SMS-Extraversion, and PONS scores.

Using the SMS-Extraversion factor, Funder and Harris (1986) did find that extraversion correlated moderately ($r = .33$, $p < .02$) with PONS-based decoding ability. Mill (1984) also found a positive correlation ($r = .40$, $p < .03$) between SMS-Extraversion and decoding ability using audio clips that varied nonverbally but held the linguistic content constant. Finally, using the EPI, Akert and Panter (1988) also found a moderate positive correlation between extraversion and decoding ability ($r = .38$, $p < .02$).

A meta-analytic combination of these effect sizes weighted by their degrees of freedom yields a small overall correlation between extraversion and decoding ability that is not statistically reliable ($r = .08$, $p > .2$). Additionally, a test for heterogeneity for all of the effect sizes indicates that the results were more variable than would be expected on the basis of sampling fluctuations alone, $\chi^2(8, N = 9) = 17.60$, $p < .03$.

Nonverbal Decoding and Multitasking

Given the heterogeneity of these results, the only strong claim one can make about the decoding advantage of extraverts is that there is no consistent evidence for it. One commonality between all of these studies, however, is that they lack components of social interactions that are present in our intuitive vision of extraverts as more effective decoders of nonverbal cues than are introverts. In each of these studies, participants had a single goal: to watch the videotape and accurately decode the nonverbal cues. Much nonverbal decoding outside the lab involves participating in, rather than simply watching, an interaction. Previous theories and experimental data tend to assume that there is a basic difference in the ability of introverts and extraverts to decode nonverbal cues. We propose that there is no difference in decoding ability itself;

however, on occasions when decoding occurs within a social interaction in which the decoder is also a participant, the demands on working memory are more troubling for introverts than for extraverts and thus lead to decoding advantage for extraverts.

Conversation Goals

An informal conversation with a new acquaintance makes many demands on the interactants, including comprehension, smooth turn-taking, generating responses, remembering one's thoughts until one's turn, and actual production of the responses. These may all be considered as part of the general process of *conversation maintenance* (CM; Swann et al., 1992). All of these CM processes occur along with our attempts to gauge how well we are being received by the other person. It is in the fulfillment of this last task, referred to as the generation of *reflected appraisals* (RA; Felson, 1993; Jussim, Soffin, Brown, & Ley, 1992; Shrauger & Schoeneman, 1979), that nonverbal decoding will play a central role. A number of studies have shown that accurate assessment of important social-evaluative cues relies more heavily on nonverbal decoding than linguistic cues (Argyle, Alkema, & Gilmour, 1972; Ekman & Friesen, 1969; Mehrabian & Wiener, 1967; Scherer, Banse, Wallbott, & Goldbeck, 1991; Swann, Stein-Seroussi, & McNulty, 1992; Zuckerman, DePaulo, & Rosenthal, 1981). Thus, to the extent that accurate RA generation occurs, so must accurate nonverbal decoding, because nonverbal decoding is one of the major subroutines invoked in RA generation.

If CM and RA generation are both effortful *controlled processes* (Baumeister, Hutton, & Tice, 1989; Gilbert, Krull, & Pelham, 1988), which rely on working memory, rather than *automatic processes*, then this would provide an explanation for why multitasking might interfere with nonverbal decoding in general. In describing the difference between automatic and controlled processes, Gilbert (1989) stated that, "[controlled] processes require significant [working memory] resources and are therefore mutually debilitating; alphabetizing words and reciting poetry are . . . activities done quite well alone but quite poorly in tandem" (p. 194). Thus, if a person's cognitive resources are depleted by either CM or RA processes, there may not be enough resources to carry out the other.

Even if CM and RA are *conditionally automatic processes* (Ambady, 1998; Ambady & Rosenthal, 1992, 1993; Bargh, 1989; Cohen, Dunbar, & McClelland, 1990), as many social psychological processes are likely to be, multitasking might still interfere with nonverbal decoding in general. Bargh (1989) has defined conditional automaticity as referring to automatic processes that are initiated, "given certain enabling circumstances, whether it be merely the presence of the triggering proximal stimulus, or that plus a specific goal-directed state of mind" (p. 7).

In the case of CM and RA being conditionally automatic processes, the goals needed to activate the underlying automatic processes would tax the central executive component of working memory that is thought to coordinate attention to goals, inhibit prepotent but inappropriate responses, and manipulate the contents of the storage components of working memory (Baddeley, 1986;

¹ Negative correlations in this section indicate that introverts demonstrated more accurate nonverbal decoding than did extraverts.

Baddeley & Hitch, 1994; Barkley, 1997). The executive system might then have to "choose" which goal to focus on to the partial exclusion of others. If nonverbal decoding is subsumed by a secondary goal, such as RA, it might well fall into the category of excluded goals.

Why might nonverbal decoding be poorer when multitasking is present than absent? Limited cognitive resources could be depleted because of attention to a more primary goal, such as CM, leaving the nonverbal decoding recruited by RA without the requisite resources to function. However, it is not yet clear why multitasking should selectively impair the nonverbal decoding of introverts but not that of extraverts. To make this final leap, the modern descendants of Eysenck's arousal theory of extraversion must be considered.

Arousal, Neurochemistry, and Multitasking

Current arousal theories of extraversion have altered the focus from individual differences in baseline arousal levels to differences in arousability, the reactivity of processing related to arousal (Brocke, Tasche, & Beauducel, 1997). The data are mixed regarding the relationship between extraversion and baseline arousal (Matthews & Gililand, 1999), in part stemming from difficulties in operationalizing arousal as a single construct (Robbins, 1997) and in part because introverts and extraverts both self-regulate their level of tonic arousal (Gale, 1973). The data are relatively clear from various psychophysiological measures, including skin conductance reactivity and event-related potentials, that introverts are more reactive than extraverts (Matthews & Gililand, 1999; Stelmack, 1990).

Arousal theories of extraversion generally invoke an inverted-U relationship between arousal and performance. Moderate levels of arousal facilitate the best performance, but beyond a certain point performance begins to drop off. Because introverts are hypothesized to have a baseline level of arousal closer to optimal, when stimuli and cognitive processing do not, in themselves, significantly raise arousal levels, introverts outperform extraverts. When the stimuli and processes do raise arousal levels, extraverts frequently outperform introverts, presumably because with the increased arousal extraverts move into the optimal performance zone and introverts move past it. Multiple studies have found that introverts more efficiently acquire conditioned responses if the stimuli are mild or neutral, but not if they are arousing (Levey & Martin, 1981; Paisley & Mangan, 1988). Similarly, Gupta and Gupta (1984) found that amphetamines, a class of stimulants, improved the conditioning of extraverts but impaired the conditioning of introverts. The same results are also easily couched in terms of reactivity rather than baseline levels of arousal, such that moderate levels of reactivity are optimal.

Arousal theories positing the inverted-U relationship have multiple limitations. First, it is not clear that all mental performances are affected by arousal levels in the same way. Some tasks show a monotonic relationship between performance and arousal (Humphreys & Revelle, 1984). Second, it is not clear why arousal or reactivity facilitates performance up to a certain point and then inhibits performance. That is, why does the higher baseline arousal or reactivity of introverts facilitate performance in low-arousal conditions but not in high-arousal conditions? Generally, trans-marginal inhibition (TMI) is invoked to explain these results by

positing that above a threshold, increasing stimulation actually reduces arousal or reactivity, or both (Brocke et al., 1997; Eysenck, 1994). TMI sounds dangerously close to a redescription of the phenomenon rather than providing actual explanatory power. The causal relationship between arousal and cognition remains something of a mystery.

Cognitive neuroscientists have recently made progress that sheds light on both the arousal-cognition relationship and the more immediate concern of why introverts should be poorer multitaskers. The closest identifiable neural concomitant of arousal in the brain is the monotonic increase in catecholamine activity associated with increases in stress (Koob, 1999). Dopamine (DA) and norepinephrine (NE), both catecholamines, increase production in response to stress (Arnsten, 1998; Finlay, Zigmond, & Abercrombie, 1995). NE levels in the thalamus relate to wakefulness indexes (Sturm et al., 1999), whereas DA activation in basal ganglia is associated with positive emotionality (Depue & Collins, 1999; Depue, Luciana, Arbisi, Collins, & Leon, 1994; Lieberman, 2000). Thus, both neurotransmitters have reasonable links to features associated with extraversion, and given that DA is the neurochemical precursor for NE (Cooper, Bloom, & Roth, 1996), perhaps the two catecholamines vary together with extraversion.

NE and DA have two other important features that help clarify the issues at hand. First, both neurotransmitters innervate the dorsolateral prefrontal cortex, which is identified with multitasking (Burgess, Veitch, de Lacy Costello, & Shallice, 2000) and the central executive component of working memory (Bunge, Klingberg, Jacobsen, & Gabrieli, 2000; D'Esposito, Postle, & Rypma, in press). Also, as indicated, this innervation is arousal dependent for both neurotransmitters. The impact of NE and DA on the functioning of prefrontal cortex follows an inverted-U pattern. Too little or too much of either NE or DA disrupts attentional and working-memory processes likely to be involved in multitasking. Furthermore, the response patterns of NE neurons differ between moderate and high levels of arousal, yielding an interaction between tonic and phasic neural activity. At moderate levels of arousal, NE neurons have a low level of tonic activity but high phasic responsivity to target stimuli (see Figure 1a). At high levels of arousal, NE neurons have a higher level of tonic activity but very little phasic responsivity to targets (see Figure 1b). Thus, at moderate levels of arousal, NE neurons are very adaptive signal detectors, with a good signal-to-noise ratio (phasic-tonic), but at high levels they become less discriminating and effectively "shut down" the prefrontal cortex (Arnsten, 1998; Aston-Jones, Rajkowski, & Cohen, 1999; Usher, Cohen, Servan-Schreiber, Rajkowski, & Aston-Jones, 1999).

These basic response properties of NE neurons in the prefrontal cortex yield optimal performance when baseline arousal is moderate and exogenous stimulation is low, or when baseline arousal is low and exogenous stimulation is moderate to high. These two conditions describe the optimal performance states for introverts and extraverts, respectively; introverts should perform better in nonarousing contexts, and extraverts should perform better in arousing contexts.

It is important to note that these effects are documented for the prefrontal cortex only. Catecholamine increases in other parts of the brain (e.g., basal ganglia) may not have inverted-U performance effects. Arousal-related DA reactivity in the basal ganglia may be related to other elements of extraversion, such as positive

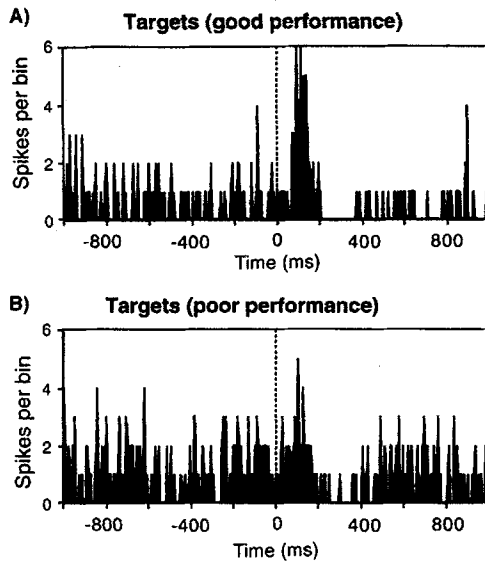


Figure 1. The response of neuropeptide neurons to a target under (a) low-arousal and (b) high-arousal conditions. The target occurs at 0 ms. From "The Role of Locus Coeruleus in the Regulation of Cognitive Performance," by M. Usher, J. D. Cohen, D. Servan-Schreiber, J. Rajkowski, and G. Aston-Jones, 1999, *Science*, 283. Copyright 1999 by American Association for the Advancement of Science. Adapted with permission.

emotionality and motor responsiveness, whereas arousal-related NE activity in the thalamus may regulate subjective wakefulness.

Returning to the main hypothesis of the current research, it now seems reasonable to suggest that introverts ought to be worse multitaskers than extraverts because multitasking is an arousing task that may lead to too much catecholamine production in the dorsolateral prefrontal cortex, impairing the introvert's capacity to multitask effectively. Extraverts, on the other hand, should thrive in multitasking situations, because the arousing qualities of multitasking bring about a very adaptive neurochemical environment in the prefrontal cortex for the multitasking.

Overview of the Studies

The preceding sections have each provided theoretical stepping stones that together inform the predictions of the current studies. To summarize, (a) extraverts have greater social competence than introverts; (b) social competence is enhanced by better nonverbal decoding; (c) people gravitate toward the nonverbal cues when trying to ascertain the affective evaluations of others; (d) contrary to what the foregoing suggest, there is little empirical evidence that extraverts are better nonverbal decoders than introverts, but (e) evidence does suggest that extraverts may have more effective working-memory processes as a result of NE-related changes in the prefrontal cortex (PFC) stemming from individual differences in arousal.

We propose that the real deficit lies in the introvert's inability to engage in multitasking as effectively as extraverts. Multitasking skill is assumed to be linked to the efficiency with which working memory can control, inhibit, and amplify various goals like CM and RA simultaneously. When nonverbal decoding occurs as the

secondary goal in a multitasking context, as is likely the case in most interpersonal interactions, introverts are expected to exhibit less accurate nonverbal decoding than do extraverts. When nonverbal decoding occurs in the absence of a multitasking context or when nonverbal decoding is the primary goal in a multitasking context, introverts are expected to be as accurate as extraverts. When nonverbal decoding is the primary goal in a multitasking context, introverts are expected to show poorer performance on whatever goal has been relegated to secondary status.

Study 1 examined the accuracy of nonverbal decoding for introverts and extraverts, in and out of a multitasking context. In Study 2, the multitasking context was always present, but the primary social goal was manipulated such that half the dyads focused primarily on CM and the other half on RA generation. In Study 3, both Study 1 and Study 2 were replicated in a multitasking design using more traditional measures of working memory and nonverbal decoding. Finally, in Study 4, introverts and extraverts were given two working-memory tasks that selectively tapped either the storage component or the central executive component of working memory to assess the nature of the working-memory differences associated with introversion.

Study 1

Overview

Introverts and extraverts engaged in an "on the phone" conversation with the target, about whom they were later required to make RA judgments. During this conversation, both CM and RA goals were assumed to be relevant to the participants, with CM being the more salient goal. CM was assumed to be more important because some degree of CM is a necessary correlate of an ongoing conversation, whereas RA generation is desirable but not necessary. After this interaction, half of the participants were asked to generate RAs, the other half listened to a tape of their conversation before generating RAs. It was assumed that during tape playback only RA goals would be salient, thus allowing introverts to perform as accurately as extraverts with the removal of multitasking demands. Study 1 examined the prediction that introverts would generate equally accurate RAs and use nonverbal cues to the same extent as extraverts when they heard the tape playback, but that without playback introverts would show deficits in both performance measures. Extraverts were expected to retain the same level of performance regardless of playback condition.

Method

Participants

The participants were 20 male and 44 female Harvard University undergraduates, who were paid \$5 to take part in this experiment. Six male and 8 female Harvard University undergraduates served as judges who coded the recorded interactions. All judges were paid \$5 per hour.

Design and Procedure

A month before the study began, participants completed the EPI (Eysenck & Eysenck, 1968), which was used to divide the sample into introverts and extraverts. This division was achieved using a median split on the Extraversion component of the EPI.

Participants were tested in dyads consisting of either 2 introverts or 2 extraverts.² Throughout the experimental session, precautions were taken to ensure that participants never saw each other. Participants arrived at two different locations in the building and were seated, one at a time, in different cubicles. Participants were also instructed not to use their names during the conversation they were about to have. These precautions ensured that later ratings would not be based on physical appearance or prior knowledge of the partner.

There was a microphone and a set of headphones in each cubicle that the participants were instructed to use throughout the experiment. This equipment was wired such that both participants and the experimenter could all communicate with each other. After the participants were situated and wearing the headphones, the experimenter instructed them to have a conversation that was to last 5 to 10 min. No topic of conversation was suggested, and participants were told that the conversation was being recorded on audiotape.

Tape-playback manipulation. In the *playback* condition, the conversation was ended after 2 min. The tape of the conversation was then played back. After tape playback, participants completed a questionnaire assessing their evaluations of their partner and their RAs. In the *no-playback* condition, the conversation was ended after 4 min. The tape was not played back for these participants. No-playback participants then completed the same questionnaire as did the playback-condition participants.

Questionnaire. The cover page of the questionnaire asked participants to answer as honestly as possible, and it informed participants that their partner would not be seeing any of their responses on the questionnaire. The first page of the questionnaire asked participants to rate the way they "felt and behaved during the conversation." The five items on this page were "How much did you like your partner?" "How much would you like to interact with your partner in the future?" "How friendly were you to your partner?" "How sensitive were you with your partner?" and "How encouraging were you to your partner?" Ratings were made on a 7-point rating scale of *not at all* to *very much*.

The second page of the questionnaire required participants to assess the way they thought their partner felt and behaved during the conversation, and it included only RA items. The five RA items on this page were "How much did your partner like you?" "How much would your partner like to interact with you in the future?" "How friendly was your partner towards you?" "How sensitive was your partner towards you?" and "How encouraging was your partner towards you?"

Dependent Measures

Accuracy of RA. One set of 7 judges listened to 30 s of each conversation on audio tape, starting from 60 s into the conversation and ending at 90 s into the conversation. The stimulus tape was constructed such that during playback each partner's voice was heard in a different ear, thus allowing judges to easily distinguish the partners from one another. Whether a participant was heard in the left or right headphone was counterbalanced across judges. For each conversation, each judge rated the affective reactions of each participant toward the other. That is, each judge answered the questions, "How much did Left like Right?" "How much did Right like Left?" "How much would Left like to interact with Right in the future?" and so on, through all the corresponding items that the participants themselves rated. Each of these ratings was made on a 7-point scale. The average judge rating for each of these items was used as a criterion of accuracy against which the participants' RA ratings were scored. Each of the participants' five RA judgments were scored against the five relevant items that the judges rated (e.g., Left's answer to "How much does your partner like you?" was subtracted from the judges' average response to "How much does Right like Left?"). Each difference score (i.e., the difference between participant and judge ratings) was squared to weight large errors disproportionately more heavily. Each participant's five squared-difference scores were summed and then averaged with the partner's sum of five squared-difference scores. Average scores were taken

across dyad members because the two participants were not experimentally independent, and thus statistical assumptions would no longer obtain if the participant, rather than the dyad, were used as the unit of analysis. It is important to note that the final index is of RA error. That is, higher scores indicate that the dyad members made less accurate RAs.

To increase the generalizability of the study, we also assessed dyad RA inaccuracy using each participant's partner's ratings as a criterion of accuracy. In this case, the left participant's answer to "How much does your partner like you?" was subtracted from the right participant's response to "How much do you like your partner?" This subtraction was carried out for each of the RA items. We then constructed the same type of index of accuracy using the squared-difference score method described above.

Accuracy of nonverbal decoding. An index of nonverbal decoding accuracy assessed the extent to which participants' RAs reflected the nonverbal cues encoded by the partner. To measure this correspondence between RAs and the partner's expressed affect in the vocal channel, a second set of 7 judges listened to content-filtered versions of the 30-s audio clips heard by the first set of judges. *Content filtering* is a process whereby the higher frequencies on an audio recording are eliminated. The resulting tape sounds like a conversation that might be heard through a wall. The tone of voice, pitch, and prosody are preserved, but almost none of the linguistic content can be identified. Judges listening to the content-filtered stimulus clips rated the same dimensions as the first set of judges. With these ratings, we used the squared-difference score method already described to construct an index of dyad use of nonverbal cues in RA generation. Higher scores on this index indicate that the RAs generated by a given dyad were more discrepant from the nonverbally expressed affect of each participant's partner.

The potential redundancy between verbally and nonverbally expressed affect from the partner raises a concern regarding the validity of this index as a measure of nonverbal decoding accuracy. Consider the case in which the same affect was expressed in both the verbal and vocal channels. The accuracy index being used would estimate the same level of nonverbal decoding accuracy whether RAs were, in fact, generated using the nonverbal or the verbal cues. For example, if the partner expressed liking in both the verbal and nonverbal channels, participants could have attended only to the verbal channel and then generated RAs that would have made them appear accurate on this nonverbal decoding index.

To safeguard against this concern, the same judges who rated the content-filtered clips also made ratings of transcripts of the conversations. The transcript ratings were then covaried out of the content-filtered audio ratings by regressing the latter onto the former, thereby removing any redundancy across the verbal and nonverbal channels. The residuals obtained in the regression represent the component of the interpersonal evaluations that was communicated only in the nonverbal channel. From these residuals, the same squared-difference accuracy index was constructed.

Results

RA Accuracy

Introverts in the no-playback condition were less accurate in their RAs of how much they were liked by their partners than were introverts in the playback condition and extraverts in both conditions. This prediction was tested using contrast weights pitting the degree of RA error for the no-playback introverts against the other three conditions (no-playback introverts, 3; no-playback extraverts, -1; playback introverts, -1; playback extraverts, -1). The

² This was done because the dyad members were not statistically independent, and consequently only a single observation could be derived from each dyad.

contrast analyses strongly confirmed the prediction whether the criterion of accuracy was the partners' ratings, $t(28) = 3.826, p < .001, r = .59$, or the judges' ratings of the full channel audio clips, $t(28) = 3.196, p < .005, r = .52$. The effective reliabilities (Spearman-Brown Up; Rosenthal & Rosnow, 1991) of the indexes of accuracy using the 7 judges' ratings of full-channel and content-filtered audio were .83 and .69, respectively. In the no-playback condition, higher levels of introversion were associated with larger RA errors: $t(14) = 1.903, p < .04, r = .45$ (judge criterion); $t(14) = 2.935, p < .005, r = .62$ (partner criterion). In the playback condition, however, introversion was not reliably correlated with RA error: $t(14) = 0.624, p > .2, r = .17$ (judge criterion); $t(14) = 0.603, p > .2, r = .16$ (partner criterion).

Nonverbal Decoding Accuracy

Introvert RA accuracy was expected to be impaired in the no-playback condition. As accurate RAs depend in large part on inferences drawn from nonverbal decoding, introverts were expected to have more difficulty activating the secondary goal of nonverbal decoding than were extraverts. To assess more directly the effect of multitasking on introverts' and extraverts' nonverbal decoding success, the extent to which participants' RAs corresponded to judges' ratings of content-filtered audio clips of the conversations was tested. Using the same contrast weights, we found that introverts in the no-playback conditions generated RAs that corresponded less with the nonverbal content of the partner's speech than did the RAs of the participants in the other three conditions, $t(28) = 3.073, p < .005, r = .50$.

The same pattern emerged from the more stringent test, in which the redundancy between verbal and nonverbal channels was removed from the ratings, $t(28) = 3.626, p < .001, r = .57$ (see Figure 2). As with the RAs, there was a marginally reliable correlation between extraversion and nonverbal decoding accuracy in the no-playback condition, $t(14) = 1.577, p < .07, r = .39$, but not in the playback condition, $t(14) = 0.691, p > .2, r = .18$. These results suggest that introverts in the no-playback condition were less able than other introverts and all extraverts to accurately decode nonverbal interpersonal cues present while they were engaged in multitasking.

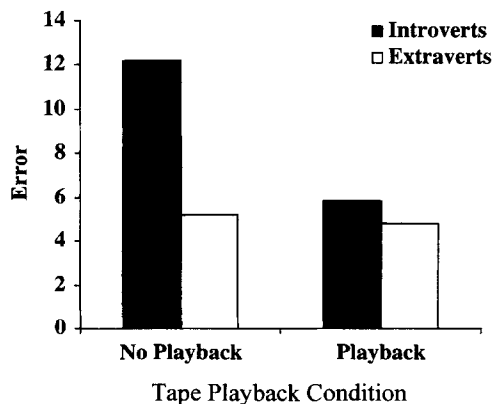


Figure 2. Nonverbal decoding accuracy (error) as a function of playback of conversation for introverts and extraverts.

Discussion

Like much of the extant research, these results indicate that introverts are just as skilled at nonverbal decoding as extraverts but that this skill may be difficult for introverts to apply in the presence of multitasking demands. When introverts were given the opportunity to listen to the conversation without having to engage in CM, they were just as accurate as extraverts in their nonverbal decoding. Only when the nonverbal decoding was performed simultaneously with the another task did introverts demonstrate poorer nonverbal decoding than did extraverts. These findings may explain why our intuition suggests that introverts are worse nonverbal decoders than extraverts despite the fact that prior studies have not found such a difference. Our intuitions about introverts and extraverts are formed mostly under conditions of multitasking (i.e., while watching people interact), whereas studies typically have controlled for multitasking by removing it from the experimental context.

Although the results of Study 1 are consistent with our predictions, they are not sufficient to establish the mediating role of multitasking demands on working memory in the decoding advantage of extraverts. First, participant goals were not explicitly manipulated. It was merely assumed that CM was the primary goal and RA a secondary goal. Second, adding tape playback to a conversation adds potentially confounding variables such as greater exposure to nonverbal cues. Perhaps introverts simply take more exposure time to make sense of the cues. Third, RA and nonverbal decoding performance were measured, but CM quality was not. According to the proposed theory, introverts should show effective performance on their primary goal, whether it is CM or RA, along with a performance decrement on their secondary goal. Measurement of both CM and RA performance is essential to test for this effect. Fourth, some might contend that CM is not an ideal proxy for working-memory load. Finally, our dyads were homogeneous as both members were introverts or extraverts, and thus our results can be interpreted in terms of the difficulty of decoding the cues of introverts while multitasking. The second and third studies remedy each of these potential methodological weaknesses of Study 1.

Study 2

Overview

Study 2 examined the impact of individual differences in introversion on the ability to engage in multitasking in the context of an "on the phone" social interaction. Unlike Study 1, all nonverbal decoding took place under the constraint of multitasking. The participants' primary goal was manipulated by specific instructions to focus on either CM or RA generation. Study 2 tested the hypotheses that (a) when given an RA goal, extraverts and introverts generate RAs of equal accuracy and use the nonverbal cues to the same degree, but introverts have a performance deficit in CM; (b) when given a CM goal, neither extraverts nor introverts demonstrate a performance deficit in CM, but introverts are less accurate in their RA generation and nonverbal decoding.

Method

Participants

Forty male and 40 female Harvard University undergraduates participated as interactants. Each was paid \$6. Five male and 9 female Harvard University undergraduates participated as judges coding the recorded interactions. Each judge was paid \$6 per hour.

Design and Procedure

The procedure was identical to that of Study 1, with two changes. First, no participants received tape playback. Second, participants received written goal-focus instructions when they were first seated in their cubicles. Instructions were manipulated between dyads. Participants in the CM-focus condition were given the following written instructions, "In just a few moments, you are going to be asked to have a conversation with another individual. During that conversation, we want you to try to have a good conversation." Participants in the RA-focus condition were given the following written instructions, "In just a few moments, you are going to be asked to have a conversation with another individual. During that conversation, we want you to try to judge how your partner is evaluating you and what your partner thinks of you in general." In both conditions, the instructions requested that participants not mention the content or existence of their instructions to their partner. In this study, all participants had 4-min conversations.

Dependent Measures

Five types of dependent measures were assessed, three for RA and nonverbal decoding accuracy and two for CM performance. The three measures of RA accuracy were the same as the measures used in Study 1, without the index that covaried the transcript ratings out of the content-filtered audio ratings. This last index was left out because in Study 1 the two nonverbal decoding accuracy indexes (with and without transcript ratings covaried out) were functionally equivalent ($r = .91$).

One set of CM measures was derived from additional ratings made by the first set of judges, who listened to the full-channel audio clips with the linguistic content intact. These judges also made ratings on six items related to CM: "How good was the conversation?" "Were the conversants at ease?" "Did the conversants need to exert effort to keep the conversation going?" "How rhythmic was the conversation?" "How well did the conversation flow?" and "Did the conversation fall apart at times?" Each of these ratings was made on a 7-point rating scale.

CM was also assessed by measuring discrete nonverbal behaviors that are thought to indicate differing degrees of CM. More backchanneling (i.e., nodding and saying "uh-huh" periodically, so the speaker knows the words are being given attention and understood) indicates better CM, whereas more awkward pauses, audible pauses, and nervous laughter indicate poorer CM.

Results

Nonverbal Decoding and Reflected Appraisals

As in Study 1, introverts who had CM as their primary goal generated less accurate RAs than did (a) introverts who had RA generation as their primary goal and (b) extraverts who had CM or RA generation as their primary goal. This pattern was substantiated by contrast analyses (CM-focus introverts, 3; CM-focus extraverts, -1; RA-focus introverts, -1; RA-focus extraverts, -1) using both judges' ratings of full-channel audio, $t(36) = 2.181$, $p < .02$, $r = .33$, and partners' ratings, $t(36) = 1.965$, $p < .03$, $r = .30$. CM-focus introverts also generated RAs that were less reflec-

tive of the nonverbal cues communicated by partners than RAs of other participants, $t(36) = 2.029$, $p < .03$, $r = .31$ (see Figure 3). The effective reliabilities (Spearman-Brown Up) of the indexes based on the 7 judges' ratings of full-channel and content-filtered audio were .63 and .63, respectively. These effects are further elucidated by the strong correlations between extraversion and nonverbal decoding accuracy in the CM-focus condition— $t(17) = 1.947$, $p < .04$, $r = .43$ (full-channel audio ratings); $t(17) = 3.76$, $p < .001$, $r = .67$ (partner ratings); $t(17) = 1.872$, $p < .04$, $r = .41$ (content-filtered audio ratings)—but not in the RA-focus condition— $t(20) = 0.375$, $p > .2$, $r = .08$ (full-channel audio ratings); $t(20) = 0.048$, $p > .2$, $r = .01$ (partner ratings); $t(20) = 0.611$, $p > .2$, $r = .14$ (content-filtered audio ratings).

CM Quality

It was predicted that when introverts, but not extraverts, engage in multitasking, their secondary-task performance suffers. Thus, introverts focusing on CM should show poorer nonverbal decoding and less accurate RA generation than all other participants. Whereas RA-focused introverts were able to accurately decode the nonverbal cues, there is some suggestion that this accuracy came at the expense of CM quality.

The six global ratings of CM quality made by judges each show at least a trend toward significance when applying contrast weights comparing RA-focused introverts with the other three conditions (CM-focus introverts, 1; CM-focus extraverts, 1; RA-focus introvert, -3; RA-focus extraverts, 1): flow of conversation, $t(38) = 1.832$, $p < .04$, $r = .28$; rhythmicity of conversation, $t(38) = 1.569$, $p < .07$, $r = .25$; ease of participants, $t(38) = 1.553$, $p < .07$, $r = .24$; continuity of conversation, $t(38) = 1.331$, $p < .1$, $r = .21$; participants exerting effort to maintain conversation, $t(38) = 1.196$, $p < .13$, $r = .19$; and conversation quality, $t(38) = 1.112$, $p < .14$, $r = .18$. These six variables were each Z-scored and then summed together to create a composite variable of global CM quality, which was marginally significant when subjected to the contrast, $t(38) = 1.515$, $p < .07$, $r = .24$. The effective reliability of the 7 judges' global ratings of CM ranged from .67 to .89, with a mean of .81.

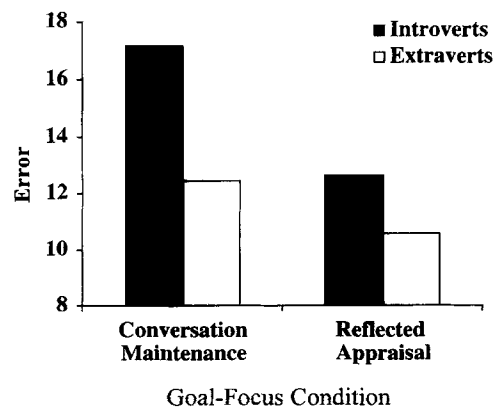


Figure 3. Nonverbal decoding accuracy (error) as a function of conversation-maintenance or reflected-appraisal goal focus for introverts and extraverts.

Judges also counted instances of discrete behaviors related to CM quality. On two of these four dependent measures, RA-focused introverts demonstrated significantly poorer CM quality (see Figure 4): awkward pauses, $t(37) = 2.066, p < .03, r = .32$; backchanneling, $t(37) = 1.697, p < .05, r = .27$; audible pauses, $t(37) = 0.894, p < .2, r = .14$; and nervous laughter, $t(37) = 0.594, p > .2, r = .10$. Introversions was correlated with both awkward pauses, $t(19) = 2.306, p < .02, r = .47$, and backchanneling, $t(19) = 1.365, p < .1, r = -.30$, in the RA-focus condition but not the CM-focus condition, $t(17) = 0.292, p > .2, r = .07$, and $t(17) = 0.212, p > .2, r = -.05$.

Discussion

A potential problem with Study 1 was the lack of explicit goal manipulation. Study 2 addressed this concern and extended the examination of performance to CM quality. As predicted, participants in the CM-focus condition showed RA and nonverbal-decoding accuracy levels that correlated with extraversion. This finding replicates the findings of Study 1 and suggests that the assumption that CM dominates in the absence of explicit goal manipulation was valid. In the RA-focus condition, introverts and extraverts were equally accurate in both their RA generation and nonverbal decoding.

There was also some evidence that the CM quality of introverts in the RA-focus condition suffered. On several measures of global and discrete behavior, introverts showed at least marginally poorer CM quality than did introverts in the CM-focus condition and extraverts in either condition.

Together, these results suggest that introverts are less able to successfully engage in multitasking. Introverts performed more poorly on their secondary goal than did extraverts, whether it was RA or CM. Extraverts showed little variation in performance as a function of goal.

Study 3

Overview

Study 3 was a conceptual replication of Studies 1 and 2 that used more controlled and traditional measures of nonverbal decoding and working-memory load. After completing the EPI, participants

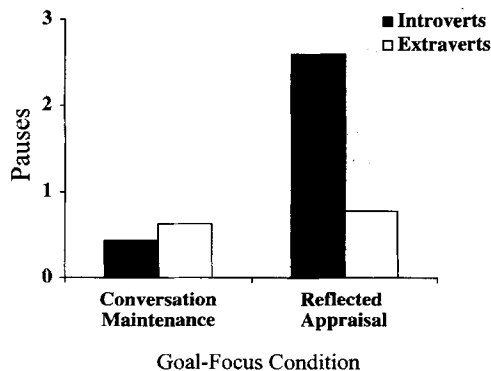


Figure 4. Number of awkward pauses as a function of conversation-maintenance or reflected-appraisal goal focus for introverts and extraverts.

simultaneously performed the audio PONS nonverbal-decoding task (Rosenthal et al., 1979) and the N-back working-memory task (at one of four levels of difficulty; O'Reilly, Braver, & Cohen, 1997). Half of the participants were instructed to give more attention to the nonverbal-decoding task (PONS-focus), and half were instructed to give more attention to the working-memory task (N-back-focus). In an additional condition, participants worked only on the PONS, without any multitasking (PONS-only). The PONS-focus and N-back-focus conditions were analogues to the RA-focus and CM-focus conditions from Study 2, respectively. The PONS-only condition was an analogue to the playback condition of Study 1.

Study 3 tested four predictions: (a) replicating Study 1, PONS-only introverts would be as accurate as PONS-only extraverts in their nonverbal decoding, but with the introduction of the easiest multitasking context, N-back-focus introverts would show poorer nonverbal decoding accuracy than N-back-focus extraverts and all PONS-only participants; (b) replicating Study 2, N-back-focus introverts would be less accurate in their nonverbal decoding than N-back-focus extraverts and all PONS-focused participants; (c) replicating Study 2, PONS-focus introverts would be less accurate in their N-back performance than PONS-focus extraverts and all N-back-focus participants; (d) with increasing N-back difficulty, extraverts would show a drop in nonverbal decoding accuracy, after an initial grace period in the easiest N-back condition. These predictions are illustrated in Table 1.

Method

Participants

The participants were 31 male and 41 female right-handed undergraduates at Harvard University. All were paid \$5 for their participation.

Design and Procedure

All participants were given the EPI in order to assess level of extraversion. Each participant then took the audio PONS test (Rosenthal et al., 1979), which is a 40-item measure of nonverbal decoding accuracy in the vocal channel. For each item, the participant hears a 2-s content-filtered clip of an adult female speaking. The participant is given a choice between two descriptions (e.g., "expressing jealousy" or "scolding a child") and is asked to determine which is the more accurate description of the audio clip. Along with the audio PONS, participants simultaneously engaged in one of the four conditions of the N-back (0, 1, 2, 3). Half of the participants completing both tasks were instructed to focus more attention on the N-back task (N-back-focus condition), and half were instructed to focus more on the PONS task (PONS-focus condition). In an additional condition, participants completed the PONS without a secondary task (PONS-only).

The N-back task (O'Reilly et al., 1997; adapted from the Continuous Performance Task [Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956]) is a target-detection task that uses working memory, with four levels of difficulty. For each level of difficulty, there is a different decision criterion for making the target response of *yes* or *no* to each of the successive letters being presented on a computer screen. In the 0-back version of the task, the participant is told to respond *yes* whenever the letter *B* is presented. In the 1-back version, the participant is told to respond *yes* whenever there is a repetition of letters with no intervening stimuli such that the repeated letter is *one back* in the sequence (e.g., *E-Q-L-[L]*). In the 2-back version, the participant is told to respond *yes* if and only if there is a repetition of letters with a single intervening letter such that the repeated letter is *two back* in

Table 1
Predictions of Nonverbal Decoding and N-Back Accuracy for Study 3

Focus	No N-back	0 back	1 back
PONS accuracy			
PONS focus			
Introvert	+	+	-
Extravert	+	+	-
N-back focus			
Introvert		-	--
Extravert		+	-
N-back accuracy			
PONS focus			
Introvert		-	--
Extravert		++	+
N-back focus			
Introvert		++	+
Extravert		++	+

Note. Predictions ranged along a spectrum, with -- predicting the lowest accuracy and ++ predicting the highest accuracy. N-back is the generic name for a set of working memory tasks that vary in difficulty, with 0-back being the easiest and 1-back more difficult. PONS = Profile of Nonverbal Sensitivity.

the sequence (e.g., *E-L-Q-[L]*). In the 2-back version, the participant is told not to respond *yes* to an immediate repetition (e.g., *E-Q-L-[L]*). The 3-back version is identical to the 2-back version except that the participant is told to respond *yes* only if there are two intervening letters between the repetition. That is, the repeated letter must be three back in the sequence (e.g., *E-L-A-Q-[L]*). In all versions of the task, both speed and accuracy were measured.

Before starting the N-back task, the experimenter explained the task and the decision criteria relevant to the participant's specific condition. Because of the complexity of the task, a simple visual aid with examples was constructed to help explain the 1-, 2-, and 3-back versions of the task to participants. The N-back task begins with 20 practice trials that are given by themselves before introducing the nonverbal decoding task. The main part of the N-back task consists of 360 letters being presented on the screen successively. Each letter is presented for 500 ms followed by a 2-s interval during which the participant is expected to press one key (*YES*) if the letter just presented meets the task's decision criteria or a second key (*NO*) if it does not. Participants were instructed to respond as quickly and as accurately as possible.

Results

Replication of Study 1 Nonverbal Decoding

In Study 1, participants were either given an opportunity to engage in nonverbal decoding without any competing task or they were required to process the nonverbal cues while continuously engaged in multitasking. In the current study, comparing the nonverbal decoding accuracy in the PONS-only condition against the N-back-focus participants, who performed the 0-back version of the task, approximates the same test from Study 1. A test that used contrast weights analogous to those from Study 1 (0-back-focus introverts, -3; 0-back-focus extraverts, 1; PONS-only introverts, 1; PONS-only extraverts, 1) showed that introverts' nonverbal decoding as a secondary task was less accurate than extraverts' nonverbal decoding as a secondary task and was less

accurate than introverts' and extraverts' nonverbal decoding when nonverbal decoding was the primary task, $t(19) = 2.128, p < .03, r = .44$. A test that used the contrast weights in Table 2 (top) showed that after the faster initial drop off in performance for introverts, who were focused on another task, both introverts and extraverts dropped off at approximately the same rate as the difficulty of the N-back task increased, $t(30) = 3.772, p < .001, r = .55$.

Replication of Study 2 Nonverbal Decoding

In Study 2, nonverbal-decoding performance was examined when the primary task was either CM or RA generation. Similarly, N-back-focus introverts who performed the 0-back task had marginally lower PONS scores than did PONS-focus introverts who performed the 0-back task and extraverts who performed the 0-back task in either focus condition, $t(19) = 1.498, p < .08, r = .33$. The same analysis of participants in the 1-back condition also revealed lower PONS scores for N-back-focus introverts than for all other participants who performed the 1-back task, $t(28) = 1.827, p < .04, r = .32$. Additionally, across the 0- and 1-back conditions, extraversion correlated reliably with PONS scores for N-back-focus participants, $t(25) = 2.38, p < .02, r = .43$, but not for PONS-focus participants, $t(39) = 0.545, p > .2, r = -.09$. Finally, the contrast weights in Table 2 (bottom) were used to test the specific pattern of results predicted by the combined hypotheses of Study 1 and Study 2. This contrast analysis strongly confirms the predictions, $t(57) = 4.15, p < .0001, r = .48, r_{\text{alerting}} = .88$ (Rosenthal & Rosnow, 1998; see Figure 5a).

PONS Scores in the 2- and 3-Back Conditions

All participants except for N-back-focused extraverts showed a surprising improvement in nonverbal decoding under the two most difficult N-back conditions (2- and 3-back). This finding suggests that participants may have shifted their multitasking strategy as the task became more difficult, though the nature of the shift is unclear. Post hoc consideration suggests that the 2- and 3-back conditions are qualitatively different from the 0- and 1-back conditions. In the 0- and 1-back conditions, only one item must be held in memory at anytime. In the 2- and 3-back conditions, the

Table 2
Contrasts Used in Study 3 to Replicate Study 1 and Studies 1 and 2 Together

Personality type and condition	No task	0 back	1 back
Int	2	-1	-4
Ext	2	2	-1
	No back	0 back	1 back
Int—PONS focus	3	3	-2
Ext—PONS focus	3	3	-2
Int—N-back focus		-2	-7
Ext—N-back focus		3	-2

Note. N-back is the generic name for a set of working memory tasks that vary in difficulty. The 0-back is the easiest version, and the 1-back is more difficult. Int = introvert; Ext = extrovert; PONS = Profile of Nonverbal Sensitivity.

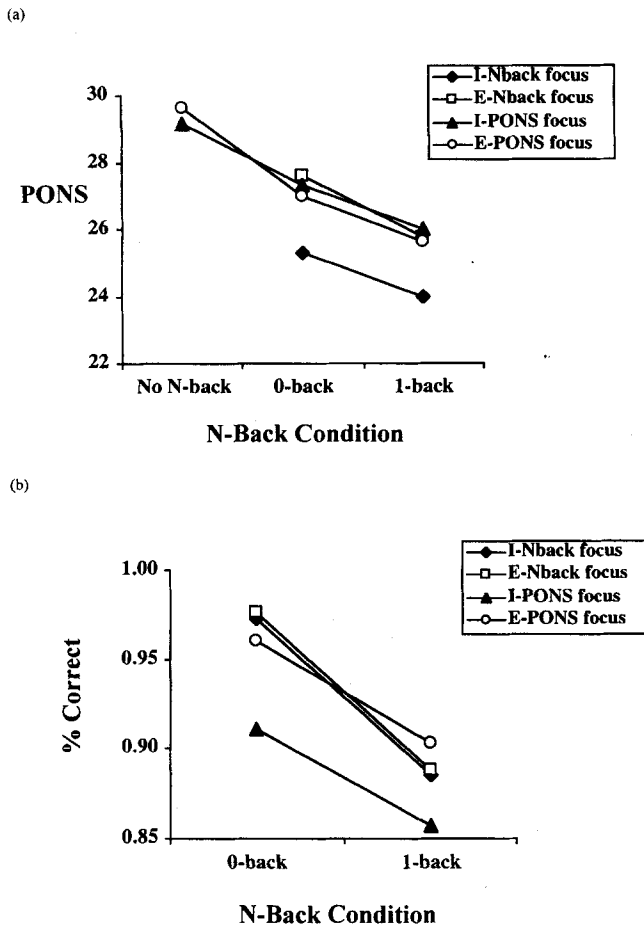


Figure 5. (a) PONS nonverbal decoding accuracy as a function of level of N-back task for introverts and extraverts under conditions of N-back or nonverbal decoding (PONS) focus. (b) N-back accuracy as a function of level of N-back task for introverts and extraverts under conditions of N-back or nonverbal decoding (PONS) focus. N-back is the generic name for a set of working memory tasks that vary in difficulty, with 0-back being the easiest and 1-back more difficult. I = introverts; E = extraverts; PONS = Profile of Nonverbal Sensitivity (Rosenthal et al., 1979).

task requires the constant updating of which letters must be kept in working memory as future targets but currently require a *no* response and which letter constitutes the current target requiring a *yes* response. In a matter of seconds, each letter changes from a distractor, to be inhibited, to a target. The 2- and 3-back conditions involve multitasking in and of themselves. Thus, the "triple-tasking" involved in combining the 2- or 3-back task with nonverbal decoding may not have been a reasonable analogue or extension of any real-world scenario.

N-Back Performance

In Study 2, there was some evidence that introverts who focused on nonverbal decoding (RA-focus) had poorer CM than did all other participants. This finding follows from the hypothesis that introverts' secondary task performance suffers more than that of extraverts. In the current study, PONS-focus introverts were less

accurate on the 0-back task, $t(21) = 2.56, p < .01, r = .51$, and the 1-back task, $t(32) = 2.44, p = .01, r = .41$, than were N-back-focus introverts and extraverts in either focus conditions (see Figure 5b). Similarly, extraversion was a good predictor of N-back accuracy for PONS-focus participants, $t(28) = 2.506, p < .01, r = .43$, but not for N-back-focus participants, $t(25) = 0.316, p > .2, r = -.06$. Somewhat surprisingly, PONS-focus extraverts were slower than all other participants on the 0-back task, $t(19) = 2.647, p < .01, r = .52$. This difference was not found in the 1-back condition, $t(30) = 0.726, p > .2, r = .13$.

Discussion

Study 3 replicated the findings of Studies 1 and 2 while controlling working-memory load and nonverbal decoding more carefully than did either of the previous studies. As in Study 1, introverts' performance on the PONS was equivalent to extraverts' performance when there was no second task dominating their goals, but introverts' performance on the PONS was poorer than extraverts' performance when there was a second task in the 0-back condition. These results demonstrate again that introverts possess the same nonverbal-decoding skill as extraverts, but when this skill is used as the secondary goal in the context of multitasking, introverts exhibit poorer nonverbal decoding. Additionally, on the 1-back task, extraverts showed a decline in their PONS scores relative to performance in the 0-back condition, which indicates that both introverts and extraverts are susceptible to multitasking interference. Extraverts, however, seem to have a larger "grace period" in their multitasking ability before interference occurs.

As in Study 2, there was a trade-off between PONS and N-back accuracy for introverts but not for extraverts. Task performance for the primary task was equivalent for introverts and extraverts, but introverts showed poorer accuracy on the secondary task, regardless of whether the PONS or N-back task was secondary.

Meta-Analysis of Studies 1-3

In each of the first three studies, correlations were reported between extraversion and nonverbal decoding accuracy under conditions of multitasking when nonverbal decoding was a secondary goal. Using meta-analytic procedures, these correlations and their associated significance tests were combined (Rosenthal & Rosnow, 1998). Before combining across studies, we combined the multiple estimates within Study 1 and Study 2 to yield one estimate per study. Each effect size was converted from r to Fisher's z_r , and then averaged with the others from the same study. Combining across studies using an unweighted means statistic, we found a moderate to large correlation between extraversion and nonverbal decoding accuracy, $Z = 3.562, p = .0001, r = .46$, but only for conditions in which (a) there was multitasking and (b) nonverbal decoding was a secondary goal (see Table 3).

Conditions that focused attention on nonverbal decoding, whether by itself or as the primary task in a multitasking context, show a much smaller correlation that was not significant despite the statistical power of combining multiple estimates, $Z = 0.885, p > .15, r = .11$ (see Table 3). It should be noted that the combined effect size of .11 is quite close to the combined effect size of .08 found for all the prior studies reviewed in the introduction, which also lacked the multitasking component. A meta-

Table 3
Correlations Between Extraversion and Nonverbal Decoding
When Performed as a Secondary Goal and as a
Primary Goal in the Context of Multitasking

Study	<i>r</i>	<i>Z</i>
Performed as a secondary goal ^a		
Study 1		
RA (judge criterion)	.45	1.76
RA (partner criterion)	.62	2.55
Nonverbal decoding	.25	0.95
Nonverbal (verbal covaried out)	.39	1.49
Study 1 average	.46	1.69
Study 2		
RA (judge criterion)	.43	1.76
RA (partner criterion)	.67	3.16
Nonverbal decoding	.41	1.82
Study 2 average	.52	2.25
Study 3		
N-back focus	.43	2.24
Performed as a primary goal ^b		
Study 1		
RA (judge criterion)	.17	0.61
RA (partner criterion)	.16	0.59
Nonverbal decoding	.20	0.74
Nonverbal (verbal covaried out)	.18	0.67
Study 1 average	.18	0.65
Study 2		
RA (judge criterion)	.08	0.37
RA (partner criterion)	.01	0.05
Nonverbal decoding	.13	0.60
Study 2 average	.08	0.34
Study 3		
PONS focus	.09	0.54

Note. N-back is the generic name for a set of working memory tasks that vary in difficulty. RA = reflected appraisals; PONS = Profile of Nonverbal Sensitivity.

^a Combined across Studies 1–3, $r = .46$, $Z = 3.56$. ^b Combined across Studies 1–3, $r = .11$, $Z = 0.89$.

analytic contrast analysis confirms that the effect sizes found under multitasking conditions in which nonverbal decoding was the secondary task were larger than those found under conditions in which nonverbal decoding was the primary task, $Z = 1.924$, $p < .03$.

Study 4

Overview

Study 4 examined the extent to which the efficiency of the central executive system and capacity of the storage system components of working memory are correlated with extraversion and thus may mediate the multitasking difference between introverts and extraverts. If the working-memory effects are a result of catecholamine differences in extraverts, then extraverts ought to have an advantage in central executive tasks that are modulated by catecholaminergic innervation of the dorsolateral prefrontal cortex. Catecholamines are not known to affect the storage system components of working memory. Social anxiety and positive affect were also measured, as both are correlated with extraversion.

Method

Participants

The participants were 11 male and 12 female Harvard undergraduates, who were each paid \$5.

Design and Procedure

Participants completed the EPI, thus allowing the experimenter to measure extraversion. Participants also completed the Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988) and a social anxiety scale (Leary, 1983). Participants were then given the digit span and N-back tasks in counterbalanced order. The digit span and the easiest levels of the N-back task are thought to selectively measure the storage component of working memory, whereas the 2 and 3-back versions of the N-back are thought to measure the central executive component of working memory (Jonides et al., 1997). A critical feature of the N-back task is that in the 2- and 3-back forms the task involves the constant updating of which letters are currently distractors—which require a *no* response but must be held in working memory because they will be targets in upcoming trials—and which letter currently constitutes a target that requires a *yes* response. In a matter of seconds, letters change status from distractor to target. At the same time, no more than three letters have to be held in storage at once. These requirements of the 2- and 3-back versions of the task (i.e., inhibiting distractors, updating the meaning of different content elements in working memory, and low storage load) suggest that it depends selectively on the central executive without heavy reliance on the storage systems. Consequently, performance on the multitasking versus non-multitasking forms of the N-back task should help illuminate which components of working memory are related to extraversion.

The procedure for the N-back task was the same as the procedure described in Study 3 except that each participant completed 25 trials for each of the different levels of the N-back task. The digit span task followed the procedure used in the Wechsler Adult Intelligence Scale—Revised (Wechsler, 1981). All digit strings were pseudorandom, with the rule that the same number could not occur twice in a given string unless the string was more than 10 digits. All number strings were presented orally to the participants at a pace of approximately one digit per second. Participants were initially given a two-digit string that was repeated back to the experimenter immediately. The participant was then given a different two-digit string to repeat back. The experimenter then presented two three-digit strings, and so on, adding a digit to the string length every two trials until the participant did not correctly recall either digit string at a given string length.

Results

Extraversion was uncorrelated with digit span performance, $t(21) = 0.178$, $p > .2$, $r = .04$. In the N-back task, extraversion was reliably correlated with faster reaction times in the 3-back, $t(21) = 2.138$, $p < .03$, $r = .42$, and 2-back conditions, $t(21) = 2.114$, $p < .03$, $r = .42$, but not in the 0-back condition, $t(21) = 0.843$, $p > .2$, $r = .18$, and it was only marginally correlated with reaction times in the 1-back condition, $t(21) = 1.633$, $p < .06$, $r = .34$ (see Table 4). A linear contrast indicated that extraversion increasingly correlated with N-back performance as the task took on a progressively larger multitasking component, $Z = 1.931$, $p < .03$, $r_{\text{alerting}} = .91$. This contrast analysis took into account the lack of independence of the correlations (Meng, Rosenthal, & Rubin, 1992). Similarly, introverts had a steeper slope for reaction times from easier to harder conditions than did extraverts, $t(21) = 1.599$, $p < .07$, $r = .33$, suggesting that a larger performance gap opened

Table 4
Correlations Between Personality Measures and Average Reaction Time on Different Levels of the N-Back Task

Personality measure	0-back	1-back	2-back	3-back
Extraversion	.18	.34	.42*	.42*
Social anxiety	-.21	-.13	-.15	-.17
Positive affect	.01	.06	.12	.01

Note. N-back is the generic name for a set of working memory tasks that vary in difficulty from 0-back (easiest) to 3-back (hardest).

* $p < .05$.

between introverts and extraverts in conditions requiring increased multitasking (see Figure 6). Slope was derived from each participant's best-fitting regression line for their reaction times across the four N-back conditions.

Given that social anxiety and positive affect have shown strong correlations with extraversion in the past, we expected these measures to correlate with multitasking performance. It was somewhat surprising that neither social anxiety nor positive affect were reliably correlated with any conditions of the N-back task (see Table 4) or digit span ($r = .10, p > .2$).

Discussion

The results of Study 4 implicate the central executive as the major component of working memory that distinguishes extraverts from introverts. Digit span, a test of storage capacity, did not differentiate introverts from extraverts, but the N-back task performance, a measure of the central executive, did. Moreover, for the N-back task, the correlation with extraversion was larger as the degree of central executive processing required by the task level increased. That is, extraversion correlated with performance more strongly in the 3-back than the 0-back condition.

Social anxiety and positive affect did not correlate reliably with any level of the N-back task or with digit span, despite its sizable correlations with extraversion. This diminishes the likelihood that the findings of the first two studies were an artifact of rumination resulting from social anxiety. The results of Study 3 also argue against a social anxiety explanation as the social interaction component was removed from the task environment. Rather, it seems more likely that a form of prefrontal cortex distraction and impaired central executive performance result from different levels of catecholamine innervation in introverts and extraverts.

General Discussion

This article began with a paradox. Multiple theories contribute to the conclusion that extraverts ought to be better nonverbal decoders: Jung (1923/1971) argued that extraverts pay more attention than introverts to the external world; Eysenck (1997) posited an arousal mechanism by which extraverts find social involvement and other arousing activities intrinsically rewarding but introverts find them intrinsically aversive; and other social scientists have suggested that introverts lack the experience that yields expertise in the subtleties of nonverbal communication (Allport, 1924; Sapir, 1958). Nevertheless, of the previous eight studies looking to

empirically verify these predictions, fewer than half found the expected advantage for extraverts in nonverbal decoding.

We have argued that two different capacities have been confused in prior work, obscuring the real relationships between extraversion, nonverbal decoding skill, and social skill. The intuition that extraverts are better nonverbal decoders is most easily derived by working backward from the evidence that extraverts possess greater social skills than introverts (Argyle & Lu, 1990b; Jenkins, 1998). Indeed, good nonverbal decoding skill is a necessary condition for successful social interactions (Swann, Stein-Seroussi, & McNulty, 1992), but it is not a sufficient condition, just as high intellectual ability is a necessary but not sufficient condition for good performance on tests of intelligence. The ability to apply the skill is nearly as important as possessing the skill itself. Some students are nervous test takers and thus are unable to demonstrate their ability. Similarly, we argue that introverts possess normal decoding skill but are unable to apply this ability under certain conditions, namely those that involve multitasking, the coordination of two tasks simultaneously.

In three studies, we have shown that introverts do have nonverbal decoding deficits, but only when the nonverbal decoding was invoked in a multitasking context and when the nonverbal decoding was the secondary, not the primary, goal. It is still possible, and thus a limitation of these studies, that our findings are specific to the decoding of auditory cues but not visual cues. However, the multitasking deficit generalized to other tasks, such as conversation maintenance (Study 2) and N-back performance (Study 3), when these tasks were secondary goals in a multitasking context, suggesting that the multitasking deficit is relatively general and not limited to decoding auditory cues or even nonverbal decoding. In a fourth study, we showed that this deficit corresponded to performance on working-memory tasks tapping the central executive component of working memory but not the storage components of working memory.

The link to the central executive component of working memory is significant because it ties the social-cognitive components of

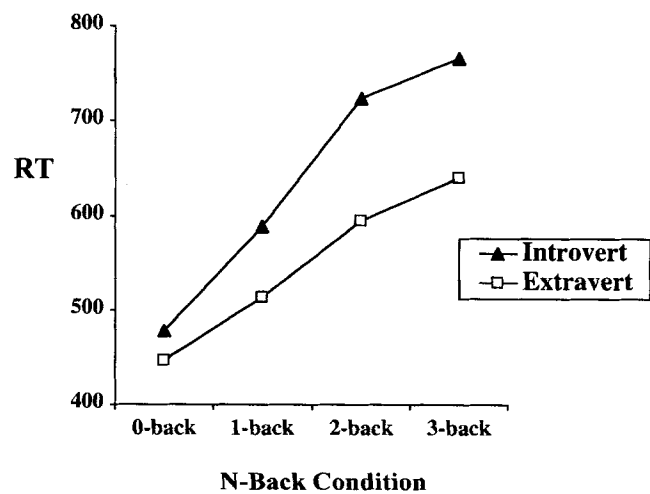


Figure 6. Reaction time (RT; in ms) as a function of level of N-back task for introverts and extraverts. N-back is the generic name for a set of working memory tasks that vary in difficulty, with 0-back being the easiest and 3-back the most difficult.

this research to the cognitive neuroscience of executive processes of working memory. The central executive is consistently linked in neuroimaging studies with activations in the dorsolateral prefrontal cortex (Bunge et al., 2000; D'Esposito et al., in press). The performance of this area is extremely sensitive to the influx of catecholamine neurotransmitters, which in turn are responsive to arousal levels (Arnsten, 1998; Aston-Jones et al., 1999; Finlay et al., 1995). Too much catecholaminergic input to the prefrontal cortex will essentially shut down the performance of this part of the cortex. This linkage thus demonstrates the importance of considering the social, cognitive, and neuroscientific levels in concert (Lieberman, 2000; Lieberman, Ochsner, Gilbert, & Schacter, in press). Arousal theory is an important piece of the puzzle here, but only when its role in affecting working memory is considered, rather than proposing a global but ill-defined role for arousal in performances of all kinds.

Heisenberg and the Introvert's Conundrum

The impaired multitasking of introverts is undoubtedly an important disadvantage for introverts in everyday life. Practically speaking, introverts are impaired in their ability to extract relevant social, affective, and evaluative cues from their interpersonal environment, because most interactions involve multitasking. Introverts' only recourse during social interactions is to make nonverbal decoding their primary goal, in which case they will be as proficient in their nonverbal decoding as their extraverted counterparts. The downside to this strategy is that their enhanced nonverbal decoding comes at the expense of conversation quality. Analogous to the Heisenberg principle in quantum physics, it may be that introverts cannot simultaneously have their best conversations and know it at the same time. This might lead to a developmental sequence in which introverts have predominately successful interactions but are only self-reflectively aware of sub-par interactions, ultimately contributing to the lower self-esteem and reduced happiness associated with introversion (Argyle & Lu, 1990b; Francis & James, 1996).

At the same time, it is important to recognize that there are many occasions on which people are observers rather than participants, and on these occasions we should expect introverts to be on equal footing with their extraverted counterparts. Introverts should be impaired only when multitasking is involved. If life were fair, we might expect introverts to have a nonverbal decoding advantage in nonmultitasking contexts, but, alas, life is not fair, and our data, as well as previous research, provide little evidence for such a claim. There is, however, evidence that introverts form better habits, show advantages in certain kinds of learning, and are more vigilant than extraverts (Corr, Pickering, & Gray, 1995b; Eysenck & Levey, 1972; Humphreys & Revelle, 1984), so no one should conclude from our data that extraverts have any global advantage over introverts.

Embedded Nonverbal Decoding

James (1890) and later Gestalt psychologists (Kohler, 1947; Wertheimer, 1944) criticized Locke, Mill, and the Wundtian introspectionists for supposing that analysis of the deconstructed components of conscious ideas and sensations was an effective path to understanding the whole-conscious datum. Studying the

ideas of table legs, tabletops, and the number four is not equivalent to studying the idea of a complete table.

A similar concern arises in the study of nonverbal decoding. It cannot be assumed that the decoding that occurs when specifically focusing on nonverbal decoding is the same process that occurs when nonverbal decoding is not in focus but rather is subserving a superordinate goal such as RA or impression formation. Understanding how nonverbal decoding functions as a process serving more traditional social goals can only complement our understanding of nonverbal decoding.

The methodology used in Studies 1 and 2 makes the investigation of studying embedded nonverbal decoding more tenable. By having different sets of judges rate verbal, nonverbal, and verbal + nonverbal material separately, estimates of the participants' use of nonverbal cues in ongoing conversations can be obtained. Certainly, there are limitations to this methodology. Currently, the method cannot be used to look at nonverbal decoding at different times during the interaction, nor can it parse out which nonverbal cues are never detected, detected but misconstrued, or detected but considered irrelevant to the more global ratings that the participant makes (e.g., liking). Still, the methodology offers advantages in ecological validity over standard methodologies in which participants watch stimuli clips and are instructed to focus solely on the task of nonverbal decoding. Beyond the advantages already mentioned, this methodology allows for the assessment of how individuals decode nonverbal cues that are self-relevant.

A Neurocognitive Systems Approach to Extraversion

Extraversion has been a fickle research target for the better part of a century. A number of plausible theories have been put forward during this time, but each ultimately can make sense of only a portion of the data. Eysenck's arousal theory primarily makes hypotheses about sensory processing. Introverts are hypothesized to be more reactive cognitively, behaviorally, and physiologically, in the absence of arousing pharmacological agents or external stimuli, but extraverts will be more reactive in cases of increased arousal. Over the years many studies have generally supported these hypotheses (Brocke et al., 1997; Matthews & Gililand, 1999; Smith, Concannon, Campbell, Bozman, & Kline, 1990; Stelmack, 1990). Arnsten's (1998) and Aston-Jones' (Aston-Jones et al., 1999) models of arousal-catecholamine-cognition relationships provide an elegant extension of Eysenck's theory, filling in key intermediaries between arousal and outcome.

There are other theories of extraversion, most notably Gray's theory (1987), in which impulsivity is a near proxy for extraversion. This theory focuses on emotional reactivity rather than sensory reactivity, suggesting that extraversion correlates with the degree of responsiveness to positive affective cues. There are a number of studies demonstrating that, compared with introverts, extraverts are more responsive to positive, but not negative, mood inductions (Larsen & Ketelaar, 1991); have greater desire for positive affect (Rusting & Larsen, 1995); and generally experience more positive affect (Watson & Clark, 1992). These findings fit well with data suggesting differential activity in the striatum of introverts and extraverts (Fischer, Wik, & Fredrikson, 1997; Johnson et al., 1999), because striatal dopaminergic activity, particularly in ventral striatum, corresponds to the encoding of positively

valenced cues (Breiter et al., 1998; Depue & Collins, 1999; Lieberman, 2000; Ochsner & Schacter, 2000).

It is important to note that each theory makes predictions toward which the other is agnostic, thus rendering each theory incomplete. Moreover, there are several findings that do not fit comfortably with either theory (Corr, Pickering, & Gray, 1995a; Derryberry & Reed, 1994; Gupta & Shukla, 1989; Matthews & Gililand, 1999). Perhaps the conflict between theories can be partly resolved by reducing the scope of each from general theories of function to theories of particular neurocognitive systems. Eysenck's theory may well accommodate most of the results associated with cortical functions in terms of reactivity of posterior cortex to sensory input and the reactivity of prefrontal cortex to executive working-memory functions (Johnson et al., 1999). Alternatively, Gray's theory may account for the impact of arousal on subcortical systems, such as striatal coding of positive affect (Fischer et al., 1997). Indeed, catecholamines also impact the functioning of the amygdala, hypothalamus, thalamus, and hippocampus, so there may be room for several more extraversion theory-modules.

The importance of examining the arousal-function relationship of each neurocognitive system separately cannot be overstressed. First, arousal is likely to lead to differential catecholamine innervation in each system (Robbins, 1997). Second, catecholamine innervation is likely to have different consequences for each system's function. Although Arnsten's model of catecholamines in the prefrontal cortex invokes the familiar inverted-*U* arousal-performance curve, other systems may have different arousal-performance curves. Indeed, following Humphrey and Revelle's (1984) conclusion that automatic processes are monotonically facilitated by arousal, we predict that subcortical structures will show a more linear arousal-performance relationship. Third, and perhaps most important, the different neural systems engage in qualitatively different kinds of computations in the service of different functions. Consequently, theories and the investigations that follow from them need to take into account what system or systems are involved in the function of interest and how that system's performance is affected by arousal.

Of course, no system in the brain is an island, as each system has bidirectional connections with several others, but particular areas of the brain, or circuits including multiple areas, are differentially involved in different functions (Kosslyn & Koenig, 1992). Nevertheless, one path in the future of personality research lies in considering the impact of arousal on different neurocognitive systems separately and then looking at the reactivity of these systems to relevant social-emotional-cognitive tasks. By adding the neurocognitive-systems level of complexity, a much clearer picture of the arousal-performance relationship in extraversion should emerge in coming years.

References

- Akert, R. M., & Panter, A. T. (1988). Extraversion and the ability to decode nonverbal communication. *Personality and Individual Differences, 9*, 965-972.
- Allport, F. H. (1924). *Social psychology*. New York: Houghton Mifflin.
- Ambady, N. (1998). [Decoding thin slices of nonverbal behavior under cognitive load]. Unpublished raw data.
- Ambady, N., & Rosenthal, R. (1992). Thin slices of expressive behavior as predictors of interpersonal consequences: A meta-analysis. *Psychological Bulletin, 111*, 256-274.
- Ambady, N., & Rosenthal, R. (1993). Half a minute: Predicting teacher evaluations from thin slices of nonverbal behavior and physical attractiveness. *Journal of Personality and Social Psychology, 64*, 431-441.
- Archer, D., & Akert, R. M. (1977). Words and everything else: Verbal and nonverbal cues in social interpretation. *Journal of Personality and Social Psychology, 35*, 443-449.
- Argyle, M. (1969). *Social interaction*. New York: Atherton Press.
- Argyle, M., Alkema, F., & Gilmour, R. (1972). The communication of friendly and hostile attitudes by verbal and non-verbal signals. *European Journal of Social Psychology, 1*, 385-402.
- Argyle, M., & Lu, L. (1990a). Happiness and social skills. *Personality and Individual Differences, 11*, 1255-1261.
- Argyle, M., & Lu, L. (1990b). The happiness of extraverts. *Personality and Individual Differences, 11*, 1011-1017.
- Arnsten, A. F. T. (1998). Catecholamine modulation of prefrontal cortical cognitive function. *Trends in Cognitive Sciences, 2*, 436-447.
- Aston-Jones, G., Rajkowski, J., & Cohen, J. (1999). Role of locus coeruleus in attention and behavioral flexibility. *Biological Psychiatry, 46*, 1309-1320.
- Baddeley, A. D. (1986). *Working memory*. New York: Oxford University Press.
- Baddeley, A. D., & Hitch, G. J. (1994). Developments in the concept of working memory. *Neuropsychology, 8*, 485-493.
- Bargh, J. A. (1989). Conditional automaticity: Varieties of automatic influence in social perception and cognition. In J. S. Uleman & J. A. Bargh (Eds.), *Unintended thought*. New York: Guilford Press.
- Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin, 121*, 65-94.
- Baumeister, R. F., Hutton, D. G., & Tice, D. M. (1989). Cognitive processes during deliberate self-presentation: How self-presenters alter and misinterpret the behavior of their interaction partners. *Journal of Experimental Social Psychology, 25*, 59-78.
- Breiter, H. C., Gollub, R. L., Weisskoff, R. M., Kennedy, D. N., Makris, N., Berke, J. D., Goodman, J. M., Kantor, H. L., Gastfriend, D. R., Riorden, J. P., Mathew, R. T., Rosen, B. R., & Hyman, S. E. (1997). Acute effects of cocaine on human brain activity and emotion. *Neuron, 19*, 591-611.
- Breuer, J., & Freud, S. (1937). *Studies in hysteria*. New York: Nervous and Mental Disease Publishing Co. (Originally work published in 1895).
- Briggs, S. R., Cheek, J. M., & Buss, A. H. (1980). An analysis of the self-monitoring scale. *Journal of Personality and Social Psychology, 38*, 679-686.
- Brocke, B., Tasche, K. G., & Beauducel, A. (1997). Biopsychological foundations of extraversion: Differential effort reactivity and state control. *Personality and Individual Differences, 22*, 447-458.
- Buck, R. (1984). *The communication of emotion*. New York: Guilford Press.
- Bugental, D. E., Kaswan, J. W., & Love, L. R. (1970). Perception of contradictory meanings conveyed by verbal and nonverbal channels. *Journal of Personality and Social Psychology, 16*, 647-655.
- Bunge, S. A., Klingberg, T., Jacobsen, R. B., & Gabrieli, J. D. E. (2000). A resource model of the neural basis of executive working memory. *Proceedings of the National Academy of Science, USA, 97*, 3573-3578.
- Burgess, P. W., Veitch, E., de Lacy Costello, A., & Shallice, T. (2000). The cognitive and neuroanatomical correlates of multitasking. *Neuropsychologia, 38*, 848-863.
- Cacioppo, J. T., Martzbe, J. S., Petty, R. E., & Tassinary, L. G. (1988). Specific forms of facial EMG response index emotion during an interview: From Darwin to the continuous flow hypothesis of affect-laden information processing. *Journal of Personality and Social Psychology, 54*, 592-604.
- Cantor, N., & Kihlstrom, J. F. (1985). Social intelligence: The cognitive basis of personality. In P. Shaver (Ed.), *Review of Personality and Social*

- Psychology: Vol. 6. Self, situations, and social behavior* (pp. 15–34). Beverly Hills, CA: Sage.
- Cohen, J. D., Dunbar, K., & McClelland, J. L. (1990). On the control of automatic processes: A parallel distributed processing account of the Stroop effect. *Psychological Review*, *97*, 332–361.
- Cooper, J. R., Bloom, F. E., & Roth, R. H. (1996). *The biochemical basis of neuropharmacology* (7th ed.). New York: Oxford University Press.
- Corr, P. J., Pickering, A. D., & Gray, J. A. (1995a). Personality and reinforcement in associative and instrumental learning. *Personality and Individual Differences*, *19*, 47–71.
- Corr, P. J., Pickering, A. D., & Gray, J. A. (1995b). Sociability/impulsivity and caffeine-induced arousal: Critical flicker/fusion frequency and procedural learning. *Personality and Individual Differences*, *18*, 713–730.
- Cunningham, M. R. (1977). Personality and the structure of nonverbal communication of emotion. *Journal of Personality*, *45*, 564–584.
- Depue, R. A., & Collins, P. F. (1999). Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion. *Behavioral and Brain Sciences*, *22*, 491–569.
- Depue, R. A., Luciana, M., Arbisi, P., Collins, P. F., & Leon, A. (1994). Dopamine and the structure of personality: Relation of agonist-induced dopamine activity to positive emotionality. *Journal of Personality and Social Psychology*, *67*, 485–498.
- Derryberry, D., & Reed, M. A. (1994). Temperament and attention: Orienting toward and away from positive and negative signals. *Journal of Personality and Social Psychology*, *66*, 1128–1139.
- D'Esposito, M., Postle, B. R., & Rypma, B. (in press). Prefrontal cortical contributions to working memory: Evidence from event-related fMRI studies. *Experimental Brain Research*.
- Ekman, P., & Friesen, W. V. (1969). Non-verbal leakage and clues to deception. *Psychiatry*, *32*, 88–105.
- Ekman, P., Friesen, W. V., & Ellsworth, P. (1972). Does the face provide accurate information? In P. Ekman (Ed.), *Emotion in the human face* (pp. 56–97). New York: Cambridge University Press.
- Eysenck, H. J. (1967). *The biological basis of personality*. Springfield, IL: Thomas.
- Eysenck, H. J. (1990). Biological dimensions of personality. In L. A. Pervin (Ed.), *Handbook of personality: Theory and research* (pp. 244–276). New York: Guilford Press.
- Eysenck, H. J. (1994). Personality: Biological foundations. In P. A. Vernon (Ed.), *The neuropsychology of individual differences* (pp. 151–207). London: Academic Press.
- Eysenck, H. J. (1997). Personality and experimental psychology: The unification of psychology and the possibility of a paradigm. *Journal of Personality and Social Psychology*, *73*, 1224–1237.
- Eysenck, H. J., & Eysenck, S. B. G. (1968). *Manual for the Eysenck Personality Inventory*. San Diego, CA: Educational and Industrial Testing Service.
- Eysenck, H. J., & Levey, A. (1972). Conditioning, introversion-extraversion and the strength of the nervous system. In V. D. Nebylitsyn & J. A. Gray (Eds.), *Biological bases of individual behavior* (pp. 206–220). London: Academic Press.
- Feldman, R. S., Philippot, P., & Custrini, R. J. (1991). Social competence and nonverbal behavior. In R. S. Feldman & B. Rime (Eds.), *Fundamentals of nonverbal behavior*. New York: Cambridge University.
- Felson, R. B. (1993). The (somewhat) social self: How others affect self-appraisals. In J. Suls (Ed.), *Psychological perspectives on the self: Vol. 4. The self in social perspective*. Hillsdale, NJ: Erlbaum.
- Finlay, J. M., Zigmond, M. J., & Abercrombie, E. D. (1995). Increased dopamine and norepinephrine release in medial prefrontal cortex induced by acute and chronic stress: Effects of diazepam. *Neuroscience*, *64*, 619–628.
- Fischer, H., Wik, G., & Fredrikson, M. (1997). Extraversion, neuroticism and brain function: A PET study of personality. *Personality and Individual Differences*, *23*, 345–352.
- Francis, L. J., & James, D. J. (1996). The relationship between Rosenberg's construct of self-esteem and Eysenck's two-dimensional model of personality. *Personality and Individual Differences*, *21*, 483–488.
- Funder, D. C., & Harris, M. J. (1986). On the several facets of personality assessment: The case of social acuity. *Journal of Personality*, *54*, 528–550.
- Gale, A. (1973). The psychophysiology of individual differences: Studies of extraversion and the EEG. In P. Kline (Ed.), *New approaches in psychological measurement* (pp. 93–122). New York: Wiley.
- Gilbert, D. T. (1989). Thinking lightly about others: Automatic components of the social inference process. In J. S. Uleman & J. A. Bargh (Eds.), *Unintended thought* (pp. 189–211). New York: Guilford Press.
- Gilbert, D. T., Krull, D. S., & Pelham, B. W. (1988). Of thoughts unspoken and the self-regulation of behavior. *Journal of Personality and Social Psychology*, *55*, 685–694.
- Goleman, D. (1995). *Emotional intelligence*. New York: Bantam.
- Gray, J. A. (1987). *The psychology of fear and stress* (2nd ed.). Cambridge, England: Cambridge University Press.
- Gupta, B. S., & Gupta, U. (1984). Dextroamphetamine and individual susceptibility to reinforcement in verbal and operant conditioning. *British Journal of Psychology*, *75*, 201–208.
- Gupta, B. S., & Shukla, A. P. (1989). Verbal operant conditioning as a function of extraversion and reinforcement. *British Journal of Psychology*, *80*, 39–44.
- Hecht, M. A. (1995). [Personality and nonverbal sensitivity]. Unpublished raw data.
- Humphreys, M. S., & Revelle, W. (1984). Personality, motivation, and performance: A theory of the relationship between individual differences and information processing. *Psychological Review*, *91*, 153–184.
- James, W. (1890). *The principles of psychology*. New York: Dover.
- Jenkins, J. (1998). *An investigation of the construct of social ability*. Unpublished manuscript. Harvard University.
- Johnson, D. L., Wiebe, J. S., Gold, S. M., Andreasen, N. C., Hichwa, R. D., Watkins, G., & Boles Ponto, L. L. (1999). Cerebral blood flow and personality: A positron emission tomography study. *American Journal of Psychiatry*, *156*, 252–257.
- Jonides, J., Schumacher, E. H., Smith, E. E., Lauber, E. J., Awh, E., Minoshima, S., & Koeppe, R. A. (1997). Verbal working memory load affects regional brain activation as measured by PET. *Journal of Cognitive Neuroscience*, *9*, 462–475.
- Jung, C. G. (1971). *Psychological types*. London: Routledge & Kegan Paul. (Original work published in 1923)
- Jussim, L., Soffin, S., Brown, R., & Ley, J. (1992). Understanding reactions to feedback by integrating ideas from symbolic interactionism and cognitive evaluation theory. *Journal of Personality and Social Psychology*, *62*, 402–421.
- Kohler, W. (1947). *Gestalt psychology*. New York: Liveright.
- Koob, G. F. (1999). Corticotropin-releasing factor, norepinephrine, and stress. *Biological Psychiatry*, *46*, 1167–1180.
- Kosslyn, S. M., & Koenig, O. (1992). *Wet mind: The new cognitive neuroscience*. New York: Free Press.
- Larsen, R. J., & Ketelaar, T. (1991). Personality and susceptibility to positive and negative emotional states. *Journal of Personality and Social Psychology*, *61*, 132–140.
- Leary, M. B. (1983). Social anxiousness: The construct and its measurement. *Journal of Personality Assessment*, *47*, 66–75.
- Levey, A. B., & Martin, I. (1981). Personality and conditioning. In H. J. Eysenck (Ed.), *A model for personality*. Berlin: Springer-Verlag.
- Lieberman, M. D. (2000). Intuition: A social cognitive neuroscience approach. *Psychological Bulletin*, *126*, 109–137.
- Lieberman, M. D., Ochsner, K. N., Gilbert, D. T., & Schacter, D. L. (in press). Do amnesics exhibit cognitive dissonance reduction? The role of explicit memory and attention in attitude change. *Psychological Science*.
- Matthews, G., & Gililand, K. (1999). The personality theories of H. J.

- Eysenck and J. A. Gray: A comparative review. *Personality and Individual Differences*, 26, 583–626.
- Mayer, J., & Salovey, P. (1997). What is emotional intelligence? In P. Salovey & D. Sluyter (Eds.), *Emotional development and emotional intelligence: Educational implications* (pp. 3–34). New York: Basic Books.
- Mehrabian, A., & Wiener, M. (1967). Decoding of inconsistent communications. *Journal of Personality and Social Psychology*, 6, 109–114.
- Meng, X., Rosenthal, R., & Rubin, D. B. (1992). Comparing correlated correlation coefficients. *Psychological Bulletin*, 111, 172–175.
- Mill, J. (1984). High and low self-monitoring individuals: Their decoding and empathic expression. *Journal of Personality*, 52, 372–388.
- Myers, I. B. (1962). *Myers-Briggs type indicator*. Princeton, NJ: Educational Testing Service.
- Ochsner, K. N., & Schacter, D. L. (2000). A social cognitive neuroscience approach to emotion and memory. In J. C. Borod (Ed.), *The neuropsychology of emotion* (pp. 163–193). New York: Oxford University Press.
- O'Reilly, R. C., Braver, T. S., & Cohen, J. D. (1997). A biologically-based computational model of working memory. In A. Maykae & P. Shah (Eds.), *Models of working memory*. Oxford: Oxford University Press.
- Paisley, T. J. H., & Mangan, G. L. (1988). Personality and conditioning with appetitive and aversive stimuli. *Personality and Individual Differences*, 9, 68–78.
- Patterson, M. (1995). Nonverbal communication. In S. R. Manstead & M. Hewstone (Eds.), *The Blackwell encyclopedia of social psychology* (pp. 405–410). Cambridge, MA: Blackwell.
- Riggio, R. E. (1986). Assessment of basic social skills. *Journal of Personality and Social Psychology*, 51, 649–660.
- Riggio, R. E., & Friedman, H. S. (1982). The interrelationships of self-monitoring factors, personality traits, and nonverbal social skills. *Journal of Nonverbal Behavior*, 7, 33–45.
- Robbins, T. W. (1997). Arousal systems and attentional processes. *Biological Psychology*, 45, 57–71.
- Rosenthal, R., Hall, J. A., DiMatteo, M. R., Rogers, P. L., & Archer, D. (1979). *Sensitivity to nonverbal communication: The PONS Test*. Baltimore, MD: Johns Hopkins University Press.
- Rosenthal, R., & Rosnow, R. L. (1991). *Essentials of behavioral research: Methods and data analysis* (2nd ed.). New York: McGraw-Hill.
- Rosenthal, R., & Rosnow, R. L. (1998). *Contrast analysis: Focused comparisons in the analysis of variance* (2nd ed.). Cambridge, England: Cambridge University Press.
- Rosvold, H. E., Mirsky, A. F., Sarason, I., Bransome, E. D., & Beck, L. H. (1956). A continuous performance test of brain damage. *Journal of Consulting Psychology*, 20, 343–350.
- Rusting, C. L., & Larsen, R. J. (1995). Moods as sources of stimulation: Relationships between personality and desired mood states. *Personality and Individual Differences*, 18, 321–329.
- Sapir, E. A. (1958). The unconscious patterning of behavior in society. In D. G. Mandelbaum (Ed.), *Selected writings of Edward Sapir in language, culture and personality* (pp. 544–559). Berkeley: University of California Press.
- Scherer, K. R. (1981). Speech and emotional states. In J. Darby (Ed.), *Speech evaluation in psychiatry* (pp. 189–220). New York: Grune & Stratton.
- Scherer, K. R., Banse, R., Wallbott, H. G., & Goldbeck, T. (1991). Vocal cues in emotion encoding and decoding. *Motivation and Emotion*, 15, 123–148.
- Schneider, R. J., Ackerman, P. L., & Kanfer, R. (1996). To “act wisely in human relations”: Exploring the dimensions of social competence. *Personality & Individual Differences*, 15, 469–481.
- Shrauger, J. S., & Schoeneman, T. J. (1979). Self-evaluation and reactions to evaluations from others. *Journal of Personality*, 43, 94–108.
- Smith, B. D., Concannon, M., Campbell, S., Bozman, A., & Kline, R. (1990). Regression and criterion measures of habituation: A comparative analysis in extraverts and introverts. *Journal of Research in Personality*, 24, 123–132.
- Snyder, M. (1974). Self-monitoring of expressive behavior. *Journal of Personality and Social Psychology*, 30, 526–537.
- Stelmack, R. M. (1990). Biological bases of extraversion: Psychophysiological evidence. *Journal of Personality*, 58, 293–311.
- Sternberg, R. J. (1985). *Beyond I.Q.* New York: Cambridge University Press.
- Sturm, W., de Simone, A., Krause, B. J., Sprecht, K., Hesselmann, V., Radermacher, I., Herzog, H., Tellmann, L., Muller-Gartner, H. W., & Willmes, K. (1999). Functional anatomy of intrinsic alertness: Evidence for a fronto-parietal-thalamic-brainstem network in the right hemisphere. *Neuropsychologia*, 37, 797–805.
- Swann, W. B., Stein-Seroussi, A., & McNulty, S. W. (1992). Outcasts in a white-lie society: The enigmatic worlds of people with negative self-concepts. *Journal of Personality and Social Psychology*, 62, 618–624.
- Trimboli, A., & Walker, M. B. (1987). Nonverbal dominance in communication of affect: A myth? *Journal of Nonverbal Behavior*, 11, 180–190.
- Usher, M., Cohen, J. D., Servan-Schreiber, D., Rajkowski, J., & Aston-Jones, G. (1999). The role of locus coeruleus in the regulation of cognitive performance. *Science*, 283, 549–554.
- Vingoe, F. J., & Antonoff, S. R. (1968). Personality characteristics of good judges of others. *Journal of Counseling Psychology*, 15, 91–93.
- Watson, D., & Clark, L. A. (1992). On traits and temperament: General and specific factors of emotional experience and their relation to the five-factor model. *Journal of Personality*, 60, 441–476.
- Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, 54, 1063–1070.
- Wechsler, D. (1981). *WAIS-R manual: Wechsler Adult Intelligence Scale—Revised*. New York: Harcourt Brace Jovanovich.
- Wertheimer, M. (1944). *Gestalt theory*. New York: Engelmann.
- Zuckerman, M. (1987). A critical look at three arousal constructs in personality theory. In J. Strelau & H. J. Eysenck (Eds.), *Personality dimensions and arousal* (pp. 217–230). New York: Plenum Press.
- Zuckerman, M., DePaulo, B. M., & Rosenthal, R. (1981). Verbal and nonverbal communication of deception. In L. Berkowitz (Ed.), *Advances in experimental social psychology*. (Vol. 14, pp. 2–59). New York: Academic Press.

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