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MOVEMENT TIME DIFFERENTIATES EXTRAVERTS FROM INTROVERTS

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Summary—67 female subjects who were classified on the Eysenck Personality Questionnaire-Revised were compared on simple reaction time and stimulus–response compatibility tasks. Response time on these tasks was defined in terms of reaction time (RT) and movement time (MT). On the simple reaction time task, the distance of the target button from the home button was varied. The stimulus–response compatibility task examined the interaction of extraversion with stimulus evaluation demands and response requirements. For both tasks, and across all conditions, the MTs of extraverts were faster than those of the introverts, but no relation with RT was observed. These results support the view that individual differences in extraversion are influenced by differences in fundamental motor mechanisms. © 1997 Elsevier Science Ltd

Keywords: extravert, introvert, reaction time, stimulus response, movement time.

INTRODUCTION

There is abundant evidence establishing introverts as more reactive than extraverts to physical stimulation. In relation to extraverts, introverts exhibit lower auditory thresholds (Stelmack & Campbell, 1974), lower pain thresholds (Schalling, 1971), greater sensitivity to noise (Dornic & Ekehammar, 1990), and larger psychophysiological responses to stimuli (Smith, Concannon, Campbell, Bozmann & Kline, 1990; Stelmack, 1990). These differences are understood in terms of the introvert's level of cortical arousal (Eysenck, 1967) or arousability (Claridge, 1967) being higher than that of extraverts, or more directly, in terms of their greater sensory sensitivity (Stelmack, 1990). However, there is another body of evidence regarding extraversion and motor expression that is not easily explained by differences in cortical arousal. For example, extraverts showed more frequent rest pauses on tapping tasks (Eysenck, 1964), greater reminiscence on pursuit rotor tracking tasks (Eysenck & Frith, 1977), and reduced levels of monosynaptic reflex recovery compared to introverts (Pivik, Stelmack & Bylsma, 1988). Such findings cannot be explained by cortical arousal, and suggest that individual differences in extraversion may be referred to fundamental motor processes. This hypothesis is examined in the present study by using simple reaction time and stimulus–response compatibility tasks. Response times are measured by differentiating reaction time (RT) and movement time (MT).

The traditional measure of response time includes the time from stimulus onset to the press of a target button. However, reaction time (RT) can be measured independently of movement time (MT) by an apparatus making use of a 'home' button. RT is recorded as the time from stimulus onset to the release of the home button, while MT is recorded as the time from this release to the subsequent press of a target button (Jensen & Munro, 1979).

It has been established that RT and MT are differentially affected by experimental parameters. RT is an index of cognitive processes and includes time relating to stimulus classification or evaluation, response selection, and programming the execution of motor movements (Welford, 1960; Theios, 1975). Evidence supporting this is derived from studies that manipulated stimulus parameters (Crossman, 1955; Thurmond & Alluisi, 1963; Nickerson, 1966; Sternberg, 1966), response sets, for example speed–accuracy trade-offs (Fitts, 1966) or stimulus–response compatibility (Fitts & Deininger, 1954), and motor execution complexity (Jensen, 1982; Klapp, 1975).

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Concerning stimulus evaluation, RT increases as a function of the amount of information in the stimulus. For example, increasing the number of elements in a stimulus set increases response time (Nickerson, 1966; Sternberg, 1966). When stimulus discriminability was decreased by increasing similarity between stimulus alternatives, response times increased (Crossman, 1955; Thurmond & Alluisi, 1963). Response times also increase as the number of target alternatives increase (Hick, 1952; Brainard, Irby, Fitts & Alluisi, 1962). MT, however, shows virtually no change (Jensen, 1982).

Regarding response bias, instructions emphasizing accuracy elicit longer RTs than those emphasizing speed (Hick, 1952; Fitts, 1966). Measures of MT followed a similar pattern, but were not statistically significant (Houlihan, Campbell & Stelmack, 1994). Stimulus–response compatibility also affects RT. Stimulus–response compatibility is a concept that uses the pairing of stimuli and responses to explain why some tasks are easier than others (Fitts & Deininger, 1954). The compatibility of a relationship is based on similarities and correspondences within the ensemble (Kornblum, Hasbroucq & Osman, 1990). Compatible response instructions elicit shorter RTs than incompatible response instructions (Fitts & Deininger, 1954), but have no effect on MT (Simon, 1969; Houlihan *et al.*, 1994).

Concerning motor execution, RT is faster when only the lift-off is required, rather than when the lift-off is to be followed by the press of a target button (Jensen, 1982). This suggests that when a target press is required, RT is longer because of the time needed to plan for the direction and speed of the movement. Some research has been carried out on the influence of various MT subcomponents on RT, including the amplitude of the initial impulse (Glencross, 1972; Klapp, 1975), movement duration (Klapp & Erwin, 1976), movement precision (Fitts & Peterson, 1964; Klapp, 1975; Glencross, 1976), average velocity (Carlton, Robertson, Carlton & Newell, 1985; Falkenberg & Newell, 1980), and force production (Carlton, Carlton & Newell, 1987). This research suggests that the movement parameters influence RT by altering the programming requirements for the organization of the response.

Although RT is useful as an index of cognitive processing speed, MT appears to be relatively independent of cognitive task requirements. The overall MT measure is only minimally affected by task difficulty, and, as such, is appropriately used as a measure of the speed of movement within responses.

The separation of the traditional response time measure into RT and MT has been carried out infrequently in personality research (but see Barratt, 1967; Rammsayer, Netter & Vogel, 1993; Rammsayer, 1995; Stelmack, Houlihan & McGarry-Roberts, 1993). Most studies involving personality variables have used an undifferentiated response time measure. Some investigators using this undifferentiated measure have found that extraverts showed faster response times than introverts (Mangan & Farmer, 1967; Zhorov & Yermolayeva-Tomina, 1972; Buckalew, 1973; Thackray, Jones & Touchstone, 1974; Keuss & Orlebeke, 1977; Brebner & Flavel, 1978; Dickman & Meyer, 1988; Robinson & Zahn, 1988), while others reported no overall differences between groups (Brebner & Cooper, 1974; Hummel & Lester, 1977; Gupta & Nicholson, 1985; Kirkcaldy, 1987; Casal, Caballo, Cueto & Cubos, 1990). These disparities have been attributed to variations in experimental parameters, with stimuli that increase stimulus evaluation demands eliciting faster response times in introverts than extraverts, and those increasing response requirements eliciting faster response times in extraverts than introverts (Brebner, 1990). Others have attributed the disparity to parameters such as interstimulus intervals, stimulus intensity, and time on task (Bullock & Gilliland, 1993; Robinson & Zahn, 1988). In general, however, no consistent association between extraversion and response time has been demonstrated. Whether the response time differences that have been reported are due to differences in reaction time, movement time, or both, remains unclear.

Cognitive psychophysiologists have often noted that RT and MT can be affected by a number of different processes, such as stimulus evaluation and response production. These measures might be useful in discriminating among proposed CNS bases for extraversion. If individual differences in extraversion are mediated by cognitive, cortical processes, these processes should exert their influence on the RT measure. However, if individual differences in extraversion are mediated by peripheral nervous system processes, then differences in MT, rather than RT would be expected since MT measures motor speed relatively independently of stimulus analysis processes.

In the present study, two tasks were used to assess individual differences in RT and MT, i.e. a simple auditory reaction time task and a stimulus–response compatibility task. The simple reaction

Table 1. Intercorrelations of personality scales for the sample ($N = 67$)

	Extraversion	Neuroticism	Psychoticism	Lie
E	—			
N	0.22*	—		
P	0.12	0.21*	—	
L	−0.21*	0.23*	0.26*	—

*$P < 0.05$, **$P < 0.01$

time task was chosen to minimize stimulus evaluation demands, and to allow for variations in motor execution requirements. Such requirements were manipulated by using three different distances between the target button and the home button. If differences between extraverts and introverts are determined by processes associated with ballistic movement, one would expect the differences in MT between groups to increase as the distance increased. The tones signalling responses were presented at two different intensities. It has been reported that higher intensity stimuli elicit faster response times than stimuli of lower intensity (Cattell, 1886; and e.g. Jaskwoski, Rybarczyk & Jaroszyk, 1994), but it is not known whether stimulus intensity affects MT. Further, stimuli of moderate intensity (85 dB) have been shown to be the most effective in eliciting differences between introverts and extraverts (Stelmack & Geen, 1992).

The stimulus–response compatibility task was chosen to explore the interaction of extraversion with stimulus evaluation and response requirements. Response requirements were manipulated by introducing compatible and incompatible responses, while stimulus evaluation processes were manipulated by using congruent and incongruent stimulus arrays. Previous studies have shown that RTs to congruent stimuli are faster than to incongruent stimuli, but no interaction with personality has been studied. Similarly, RTs under compatible response conditions have been shown to be faster than under incompatible conditions, but again, no interaction with personality has been examined. If extraversion is mediated by central response organizing processes, with extraverts 'geared to respond' (Brebner, 1990), there should be interactions observed with the RT measure. Specifically, under incompatible response conditions, the RTs of extraverts should increase to a lesser degree than the RTs of ambiverts and introverts. However, if extraversion is mediated by peripheral nervous system processes, little interaction with personality should be evident in RT, but substantial variation would be expected in MT, with extraverts exhibiting faster MTs than ambiverts and introverts under all conditions.

METHOD

Participants

67 female university students volunteered their participation for the experimental session. The age of the participants ranged from 18 to 30 yr (M = 22, S.D. = 3). The participants were selected on the basis of scores on the extraversion scale of the Eysenck Personality Questionnaire-Revised (EPQ-R; Eysenck & Eysenck, 1991) to form three groups, with introverts scoring 0–11, ambiverts 13–17, and extraverts 18–23. The intercorrelations between the personality scales of the EPQ-R are reported in Table 1, and the mean scores of the extraversion groups on the EPQ-R scales are reported in Table 2. There were no significant differences in age or personality score distribution between the samples for each task. Of the 67 participants, 50 completed both the simple reaction time task and stimulus–response compatibility tasks. Seven participants took part only in the simple reaction time task ($N = 57$) and ten others only in the stimulus–response compatibility task ($N = 60$).

All participants were right-handed, had normal hearing (thresholds less than or equal to 15 dB

Table 2. Mean scores (and standard deviations) on the personality scales for the groups participating in the experiments

	Extraversion	Neuroticism	Psychoticism	Lie
Extraverts	20.4 (1.2)	11.7 (5.2)	5.9 (4.0)	6.5 (4.2)
Ambiverts	15.4 (1.6)	10.7 (3.3)	5.1 (3.3)	7.7 (4.1)
Introverts	6.0 (2.7)	14.6 (5.2)	6.3 (4.6)	8.7 (4.6)

SPL when tested at 500 Hz), had normal or corrected to normal vision, no motor impairments, and were not taking any medication other than oral contraceptives. Because correlations between RT and measures of mental ability have been reported, participants were also asked to report their grade point average, or, in the case of first year students, their average grade to date.

Apparatus

A response box was constructed with a home button, and target buttons to the left and right of the home button. RT was defined as the time from target stimulus onset to the release of the home button, and MT as the time from the release of the home button to the press of a target button. In the simple reaction time task, three blocks of stimuli were presented, each requiring the use of a different target button located at either 7, 15, or 23 cm (angled at 30°, 65°, and 75°, respectively) to the left of the home button. The stimulus–response compatibility task used the home button, and two target buttons, each 7 cm to the left and right of the home button. Templates were used to reveal only the buttons used in that block of trials and mask the unused buttons. The same finger that was kept on the home button was used for responding.

Procedure

Participants were seated 0.5 m in front of a computer monitor in a sound-attenuated room. They were instructed to continually depress the home button until the signal to respond was given.

Simple reaction time task

The requirement to respond was signalled by the presentation of target tones, having a duration of 105 msec and a rise and fall time of 5 msec, 500 Hz, and 70 and 85 dB SPL. The intertrial interval, from the onset of one trial to the onset of the subsequent trial, was 3000 msec. Three blocks of 120 trials were presented, with intensities presented in random order with equal probability. The response button was located either 7, 15, or 23 cm from the home button. The order in which the distances were presented was counterbalanced across participants.

Stimulus–response compatibility task

The stimulus array comprised a set of arrows presented in the center of the monitor in black characters against a white background. The arrow arrays were either congruent, i.e. all pointing in the same direction (> > > > > or < < < < <) or incongruent, with the middle arrow pointing opposite to the flanking arrows (> > < > > or < < > < <). Participants were instructed to focus on the middle arrow. The stimulus array was preceded by an instructional cue word, indicating whether the response was to be compatible or incompatible with the direction of the middle arrow. If the cue word was 'SAME', participants were to respond by pressing a target button located in the same direction as the middle arrow pointed (compatible response). If the cue word was 'OPPOSITE', participants were to respond by pressing the target button located in the direction opposite that of the middle arrow (incompatible response). Thus, there were four conditions, congruent stimuli with (1) compatible and (2) incompatible instructions, and incongruent stimuli with (3) compatible and (4) incompatible instructions.

The cue word was presented for 300 msec, followed by a 200 msec pause (blank screen), then the target stimulus (arrow array) was presented for 900 msec. The next cue stimulus appeared 1 sec later resulting in a trial-to-trial interval of 2400 msec. The presentation order of stimulus conditions was randomized, but the same sequence was presented to each participant. Each of the four conditions was presented 150 times, for a total of 600 trials. A recess of 2–5 min was given after every 200 trials. Participants were given practice trials in blocks of 25 to familiarize them with the paradigm. These were repeated until 75% accuracy was attained.

In both tasks, RT and MT scores for each participant were the mean median times for each condition. Only trials to which a correct response was made were included in the RT and MT calculations.

Statistical analysis

For the simple reaction time task, RT, MT, and accuracy data were analysed using a three-way ANOVA, with group (extravert, ambivert, introvert) as a between-*Ss* factor and repeated measures on distance (7, 15, and 23 cm) and intensity (70, 85 dB SPL) factors. The effects of the order in which the target distances were presented were analysed in an additional three-way ANOVA, with order as the between-*Ss* factor, and repeated measure factors on distance (7, 15, and 23 cm) and intensity (70, 85 dB SPL). Although the Greenhouse–Geisser procedure for adjusting confidence levels with repeated measures was used, no changes resulted.

For the stimulus–response compatibility task, RT, MT, and accuracy data were analysed with a three-way ANOVA, with group (extravert, ambivert, introvert) as a between-*Ss* factor and repeated measures on stimulus congruency (congruent, incongruent) and response compatibility (compatible, incompatible) factors.

All *post hoc* analyses were conducted using Tukey's Honest Significant Difference test.

Pearson correlations were also calculated between personality scores and the dependent variables for each condition.

RESULTS

Simple Reaction Time Task

There were no significant main effects or interactions related to the order in which the target distances were used for either RT ($F<1$) or MT ($F<1$).

Reaction time

Consistent with previous literature, RTs to the 85 dB stimuli (279 msec) were significantly faster than to the 70 dB signal stimuli (291 msec), $F(1,54)=52.11$, $P<0.001$. There were no significant differences in RT between the extraversion groups ($F<1$), or among the three response button distances, $F(2,108)=2.63$, $P<0.08$. Interactions between group and distance, group and stimulus intensity, and distance and stimulus intensity were all nonsignificant ($F<1$). The interaction between group, distance, and stimulus intensity was also nonsignificant, $F(4,108)=1.54$, $P=0.20$.

Movement time

As expected, there was a main effect of distance on MT measures, $F(2,108)=253.8$, $P<0.001$. MT increased substantially with increased distance to the response button, from 165 msec for the 7 cm distance, to 232 msec for 15 cm, and 273 msec for 23 cm. Differences in stimulus intensity did not elicit differences in MTs ($F<1$).

There was a significant main effect of group on MT, $F(2,54)=4.70$, $P<0.013$. Values for introverts were significantly slower than those for ambiverts and extraverts across all conditions (see Fig. 1). Ambiverts and extraverts did not differ significantly from each other on this measure. It is important to note that the magnitude of the difference in MT between the extraversion groups was constant across the three response button distances, i.e. extraverts moved between 40 and 46 msec faster than introverts in each of the target button distances. This finding implies that the process contributing to the difference in MTs between extraverts and introverts has its influence at the initial phase of the movement time component.

All two-way interactions and the three-way interaction were nonsignificant ($F\leq 1$).

Owing to the significant correlation between extraversion and neuroticism (see Table 1), partial correlations were calculated. When controlling for neuroticism, correlations between extraversion and MT remained significant, ranging from $r=-0.41$ ($P=0.001$) at 7 cm, to $r=-0.32$ ($P=0.01$) at 15 cm, to $r=-0.31$ ($P=0.01$) at 23 cm (see Table 3). However, when controlling for extraversion,

Table 3. Partial correlations between personality scores and movement time on the simple reaction time task when controlling for neuroticism

	Extraversion	Psychoticism	Lie
MT 7 cm	−0.41***	−0.07	−0.05
MT 15 cm	−0.32**	0.13	−0.06
MT 23 cm	−0.31**	0.15	−0.01

**$P<0.01$, ***$P<0.001$ (one-tailed test)

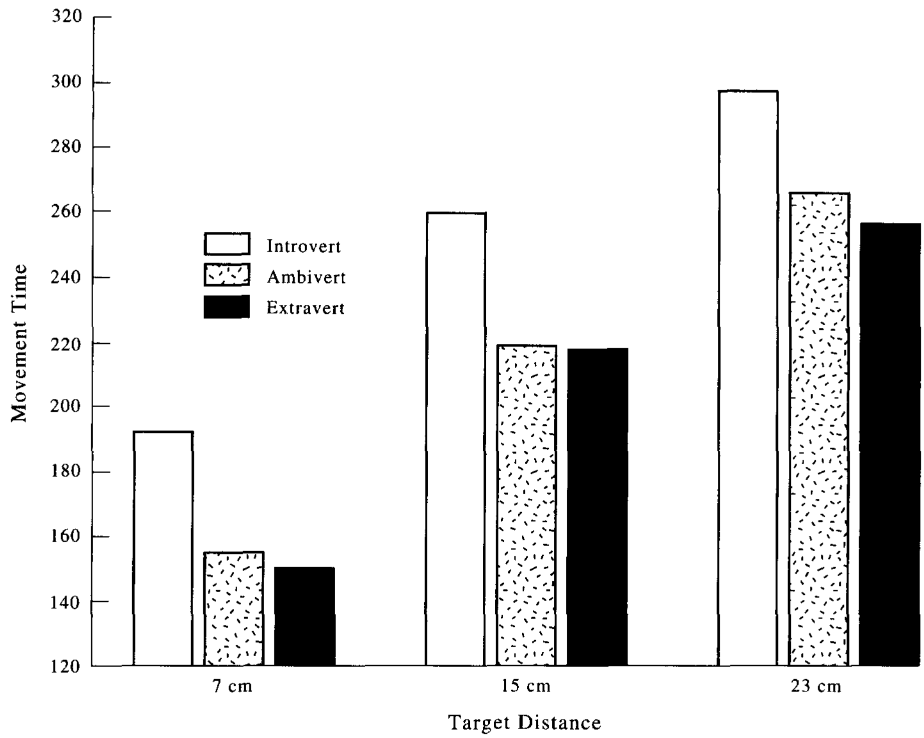

Fig. 1. Movement times of the three extraversion groups on the simple reaction time task. Introverts showed significantly slower movement times than ambiverts and extraverts when the response button was 7, 15, and 23 cm from the home button.

correlations between neuroticism and MT dropped below significance levels, ranging from $r=0.01$ ($P=0.31$) to $r=0.20$ ($P=0.07$). This indicates that the differences in MT between extraversion groups are not due to neuroticism.

RT and MT were positively correlated ($r=0.51$, $P<0.001$) as were RT and MT standard deviations ($r=0.56$, $P=0.001$). These correlations indicate that when cognitive demands are minimal, as in a simple reaction time task, RT and MT are affected by a common underlying factor, a finding in agreement with past research (Jensen, 1982). These factors might include the MT parameters of velocity and force production (Carlton *et al.*, 1987).

Accuracy and errors

Because extraverts are thought to select response strategies favouring speed, while introverts select strategies favouring accuracy (Frith, 1971), accuracy and error rates were also analysed. The analysis included several measures: (1) the number of correct responses; (2) the number of anticipatory errors (fast responses), i.e. responses occurring prior to, and within 100 msec of stimulus onset, and (3) omission errors, in which the participant failed to respond. Another type of error is error of commission, occurring when the participant missed the target button or hit the wrong button. These latter errors made up 0.01% of the responses, and were not analysed.

Accuracy rates reflected differences relating to task manipulations. Accuracy decreased as the target distance from the home button increased, $F(2,106)=6.01$, $P<0.003$, indicating that the further distances were more difficult to reach accurately. Accuracy also decreased as the stimulus intensity increased, $F(1,53)=4.78$, $P<0.03$. There were no group differences ($F<1$). Introverts did not appear to select an accuracy strategy over speed, nor did extraverts sacrifice accuracy for speed in this task. All two-way and three-way interactions were nonsignificant ($F\leq 1$).

Errors categorized as omissions did not reveal any significant effects for group ($F<1$), target distance, $F(2,106)=1.03$, $P<0.36$, or intensity ($F<1$). All interactions were nonsignificant ($F<1$).

There were more fast response errors made with the 15 and 23 cm distances than with the 7 cm distance, $F(2,108)=5.70$, $P<0.004$, perhaps these were made in an attempt to compensate for the further distance to be travelled. There were also more fast response errors to the 85 dB stimuli than

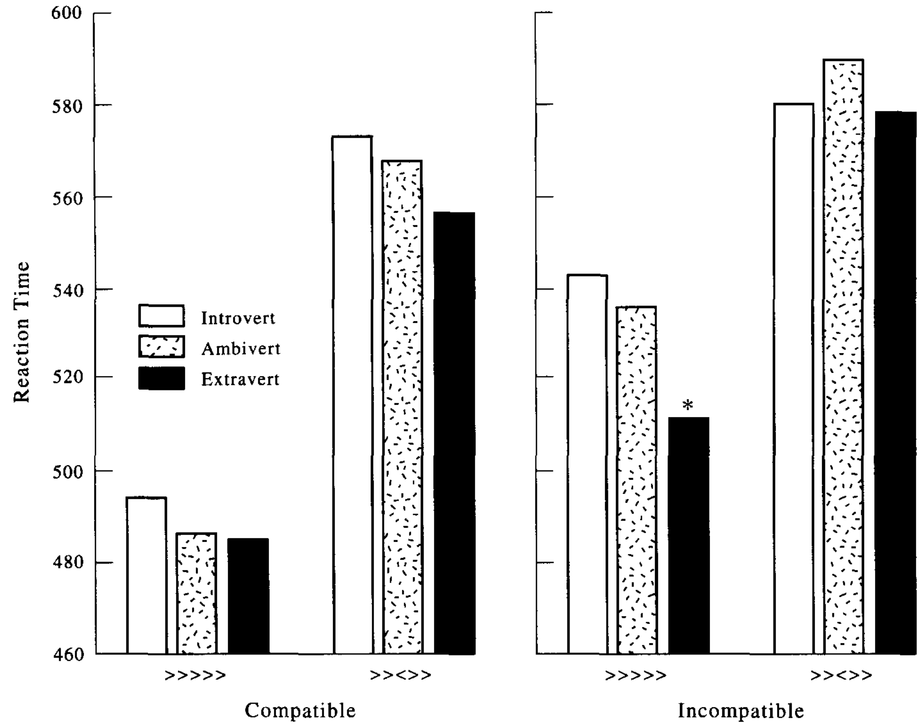

Fig. 2. Reaction times of the three extraversion groups on the stimulus–response compatibility task. The RT of extraverts was significantly faster than that of introverts and ambiverts in the incompatible–congruent condition, as indicated by an asterisk.

to the 70 dB stimuli, $F(1,54)=4.09$, $P<0.05$. There were no group differences ($F<1$). All interactions were nonsignificant ($F<1$).

Correlational analysis revealed that RT was correlated with fast response errors in the 7 and 15 cm conditions, ranging from $r=-0.26$ ($P=0.05$) to $r=-0.37$ ($P=0.004$). Because fast response errors are not included in the RT data, this correlation indicates that the participants who tended to make fast response errors also had faster legitimate RTs.

Stimulus–Response Compatibility Task

Reaction time

RTs to congruent stimuli were faster (509 msec) than those to incongruent stimuli (574 msec), $F(1,57)=174.04$, $P<0.0001$. RTs under compatible response instructions were faster (527 msec) than those under incompatible response instructions (556 msec), $F(1,57)=43.17$, $P<0.0001$. There was also a significant interaction between congruency and compatibility, $F(1,57)=21.17$, $P<0.001$). Compatible responses were faster than incompatible responses, especially when stimuli were congruent. Although there was no main effect of group ($F<1$), there was a three-way interaction between group, congruency and compatibility (see Fig. 2). The RTs of extraverts were faster than those of introverts and ambiverts in the incompatible congruent condition, $F(2,57)=4.30$, $P<0.018$ (means were 510, 536, and 543 msec for extraverts, ambiverts, and introverts, respectively). There were no significant differences in the other conditions. This indicates that extraverts respond to the demands of response incompatibility faster than introverts or ambiverts.

Correlations between RT and MT (ranging from $r=0.18$ to $r=-0.10$) were not significant. This result contrasts with the significant RT–MT correlations in the simple reaction time task, indicating that although RT and MT share an underlying common factor, there are also processes which affect these measures independently. Perhaps this only becomes evident when the cognitive demands or the response production demands are increased. Nevertheless, it is clear that although the two measures are related, there is some justification for considering RT and MT independently.

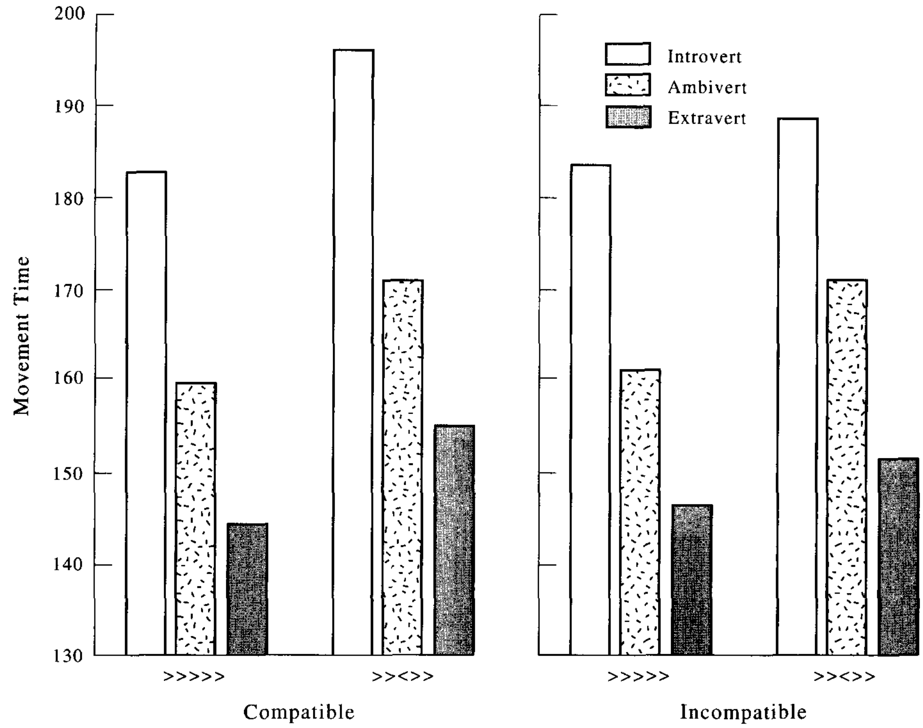

Fig. 3. Movement times of the three extraversion groups on the stimulus–response compatibility task. Extraverts had faster movement times than ambiverts, and ambiverts had faster movement times than introverts in each condition.

Movement time

There was a main effect of stimulus congruency, with MTs in the congruent stimulus conditions approximately 9 msec faster than in the incongruent stimulus conditions (163 vs 172 msec), $F(1,57)=20.72$, $P<0.001$. Although the magnitude of the difference is small, it replicates an effect reported in the literature (Houlihan *et al.*, 1994). The flanking arrows in an incongruent array may exert an inhibition over responses and affect MT in the same way as it does RT. This inhibition appears to operate even after the response process has been initiated, and thus affects MT. An alternative explanation is that there may be additional processing of the stimulus, which continues even while the response is in progress. Response compatibility had no main effect on MT, $F(1,57)=1.16$, $P<0.29$. Response compatibility interacted with congruency, $F(1,57)=5.27$, $P<0.03$; the movement times of incompatible–incongruent responses were 4 msec faster than the movement times of the compatible–incongruent responses.

Across all conditions, the MTs of extraverts were faster than those of introverts, $F(2,57)=4.14$, $P<0.02$ (see Fig. 3). *Post hoc* analyses showed that in each condition, the MTs of the extraverts were faster than those of either ambiverts or introverts, and furthermore, that the MTs of the ambiverts were faster than those of the introverts. Extraverts were consistently 38–42 msec faster than introverts. This narrow range of difference argues that the variation in MT attributable to extraversion remains constant across differences in task difficulty.

Again, because of the significant correlation between extraversion and neuroticism, partial correlations were calculated. When controlling for neuroticism, correlations between extraversion and MT were significant, ranging from $r=-0.30$ ($P=0.01$) to $r=-0.40$ ($P=0.001$) (see Table 4). However, when controlling for extraversion, correlations between neuroticism and MT dropped below significance levels, ranging from $r=0.12$ ($P=0.17$) to $r=0.18$ ($P=0.08$). It is again evident that differences in MT are largely attributable to extraversion.

Accuracy and errors

Analyses of accuracy and errors for the stimulus–response compatibility task proceeded along the same lines as the simple reaction time task. Accuracy rates reflected differences owing to task

Table 4. Correlations between movement time and personality scores on the stimulus–response compatibility task when controlling for neuroticism

	Extraversion	Psychoticism	Lie
MT CC	−0.40***	−0.01	−0.16
MT CI	−0.33**	−0.08	−0.12
MT IC	−0.39***	−0.09	−0.11
MT II	−0.30**	−0.11	−0.17

CC is compatible, congruent; IC is incompatible, congruent; CI is compatible, incongruent; IIis incompatible, incongruent
**$P<0.01$; ***$P<0.001$ (one-tailed test).

manipulations. The presentation of congruent stimuli resulted in more accurate responses than incongruent stimuli, $F(1,57)=24.61$, $P<0.001$, and compatible response instructions resulted in higher levels of accuracy than did incompatible response instructions, $F(1,57)=13.11$, $P<0.001$, but there was no effect of group ($F<1$).

There were no significant differences in regards to fast responses errors and effects for group ($F<1$), congruency ($F<1$), or compatibility ($F<1$).

The analysis of omission errors revealed main effects of task, with congruent stimuli eliciting less of this error than incongruent stimuli, $F(1,57)=19.88$, $P<0.001$, and compatible instructions eliciting less than the incompatible instructions, $F(1,57)=6.53$, $P<0.01$. Although there was no main effect of group, $F(2,57)=1.95$, $P<0.15$, there was an interaction between group and congruency, $F(2,57)=3.13$, $P<0.05$. *Post hoc* analysis revealed that introverts withheld their responses significantly more often than extraverts in all conditions except the compatible–congruent condition.

Correlational analysis revealed that RT was correlated with accuracy, such that as accuracy increased, RT was faster. Correlations ranged from $r=-0.38$ ($P=0.003$) to $r=-0.56$ ($P=0.001$). This suggests that participants who tended to respond accurately also tended to respond faster.

Both RT and MT were correlated with omission errors, such that as the number of errors increased, RT and MT slowed. Correlations ranged from $r=0.49$ ($P=0.001$) to $r=0.67$ ($P=0.001$) for the RT data, and from $r=0.37$ ($P=0.004$) to $r=0.45$ ($P=0.001$) for the MT data. This indicates that participants who tended to withhold responses also tended to have slower RTs and MTs.

Significant correlations also emerged between extraversion and omission errors in the incompatible response conditions, such that participants tending toward introversion also tended to withhold incompatible responses. Correlations were $r=-0.25$ ($P=0.05$) for the incompatible–congruent condition, and $r=-0.29$ ($P=0.03$) for the incompatible–incongruent condition.

DISCUSSION

The most salient result to emerge from the data was that extraverts exhibited faster movement times than introverts. This difference was apparent in both the simple reaction time task and the stimulus–response compatibility task. The simple reaction time task addressed the issue of whether the faster response times of extraverts which have been reported in the literature were due to the RT or the MT component. In the present study, it is clear that MT, not RT, differentiates introverts from extraverts. This effect endorses other studies that measured MT and personality (Barratt, 1967; Rammsayer *et al.*, 1993; Stelmack *et al.*, 1993; Rammsayer, 1995).

The fact that RT showed no overall correlation with extraversion suggests that extraversion is not related to either stimulus evaluation or response selection processes. Instead, as indicated above, extraversion–introversion differences are associated with motor processes that occur after RT. If the ballistic requirements of the simple reaction time task influenced the differences in MT between introverts and extraverts, the magnitude of the differences between groups would increase as the distance increased. Instead, it was observed that the magnitude of the differences remained constant. This means that the difference between introverts and extraverts is present within the first 7 cm (the shortest distance). In a previous study (Stelmack *et al.*, 1993), a correlation of −0.39 was observed between extraversion and MT, even though the *Ss* moved only 2 cm on a computer mouse. Thus, it is the early phase of MT, rather than the later ballistic phase, that is associated with differences in extraversion. It is likely that introverts and extraverts have equal average velocities, or equal peak velocities, but extraverts accelerate to that velocity faster than introverts.

The task manipulations elicited anticipated differences. In the simple reaction time task, responses were initiated faster to 85 dB tones than to 70 dB tones, following reports in the literature (Cattell, 1886; Jaskwoski *et al.*, 1994). In the stimulus–response compatibility paradigm, all groups responded more slowly to incongruent than to congruent stimuli, and incompatible response instructions elicited slower RTs than compatible response instructions. These findings were also expected based on past research (Fitts & Deininger, 1954; Crossman, 1955).

The stimulus–response compatibility results on the RT data showed a significant group by stimulus congruency by response compatibility interaction. These results follow the same pattern as those found by Bashore (1990) using an undifferentiated response time measure. Although Bashore did not report any statistical analysis, he described the effect in terms of the 'cost' of incompatibility. When congruent stimuli are compared under compatible and incompatible response instructions, a significant increase in RT is observed in the incompatible response condition. Similarly, when incongruent stimuli are compared under compatible and incompatible response instructions, an increase in RT is again observed, although this time to a lesser, even nonsignificant degree. Bashore referred to this pattern as the reduced cost of incompatibility when an incongruent array was presented. He suggested that when an incongruent array was presented, the flanking arrows in that array may actually facilitate a response away from the direction the middle arrow pointed; in effect, the incongruent array facilitated the incompatible response. This explanation appears plausible and is supported by the present study.

The effect of congruent stimuli eliciting faster MTs than incongruent stimuli is a replication of the effect obtained by Houlihan *et al.* (1994). Although the MTs elicited by congruent and incongruent stimuli differ by only 9 msec, the consistent pattern of the results, both within and between experiments, suggests that MT is at least minimally affected by ongoing stimulus evaluation within the MT phase. Although MT is affected to a small extent by stimulus congruency, it is affected more extensively by personality factors.

One possible contributor to the MT differences may have been motivation. It is well recognized that introverts tend to self-select strategies that match position (accuracy strategy), while extraverts tend to adopt strategies that match velocity (speed strategy) (Frith, 1971). It is possible that despite the instructions to move as quickly as possible, the introverts simply did not move as fast as they could have. Extraverts often commented that since they found the task boring, they imagined that it was a competitive game of some sort. However, if lack of motivation played a part in the results, it should have been observable in both the RT and MT data. The lack of differences in the RT data argues against such motivational effects. Any lack of motivation should also have resulted in a stronger negative correlation as distance to the target increased, rather than the weaker correlation that was observed.

It is clear that research involving response time measures needs to differentiate RT and MT. While the field of intelligence has recognized this need, and often considered MT a mere nuisance variable, in personality research it is evidently vital. Further research using subcomponents of the MT process is warranted to determine whether the differences are due to the acceleration to peak velocity, as suggested by this study, or to other movement parameters. Another possible area for differences would be in the approach to the target. It is known that introverts self-select accuracy over speed strategies (Frith, 1971). Although no differences were observed with regard to strategy and extraversion in this study, there may still be differences in the speed of approach, or the distance at which the slowing phase begins.

The faster MTs shown by extraverts complement the reports of behavioural differences observed between extraverts and introverts, with extraverts moving more frequently (Howarth, 1964; Gale, 1969; Hocking & Robertson, 1969), and more extensively (Wallach & Gahm, 1960; Taft, 1967) than introverts. A related area of research is the biochemical bases of the differences in motor processes. The stimulus–response compatibility task is particularly useful in that it comprises a paradigm adaptable to the exploration of the biochemical bases. Studies that manipulate neurotransmitters, for example, AMPT modulation of dopamine (Rammsayer *et al.*, 1993), could use such a task to separately analyse the neurochemical influence on stimulus evaluation and response-related processes. From any perspective, MT provides important information regarding processes underlying extraversion differentiation.

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