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Attribution and Social Cognitive Neuroscience: A new approach for the "online-assessment" of causality ascriptions and their emotional consequences

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ABSTRACT

Attribution theory plays a central role in understanding cognitive processes that have emotional consequences; however, there has been very limited attention to its neural basis. After reviewing classical studies in social psychology in which attribution has been experimentally manipulated we developed a new approach that allows the investigation of state attributions and emotional consequences using neuroscience methodologies. Participants responded to the Erikson Flanker Task, but, in order to maintain the participant's beliefs about the nature of the task and to produce a significant number of error responses, an adaptive algorithm tuned the available time to respond such that, dependent on the subject's current performance, the negative feedback rate was held at chance level. In order to initiate variation in attribution participants were informed that one and the same task was either easy or difficult. As a result of these two different instructions the two groups differed significantly in error attribution only on the locus of causality dimension. Additionally, attributions were found to be stable over a large number of trials, while accuracy and reaction time remained the same. Thus, the new paradigm is particularly suitable for cognitive neuroscience research that evaluates brain behaviour relationships of higher order processes in 'simulated achievement settings'.

1. Introduction

Social Psychology and Neuroscience have developed primarily independently, however, more recently, studies using combined methodologies and theoretical approaches have begun to elucidate the neural basis of social cognition. This has been referred to as Social Cognitive Neuroscience (for comprehensive reviews see Adolphs, 2001 or Amodio and Frith, 2006). There has been, however, very limited investigation of the neural bases of attributions, even though they have been shown to interact with numerous psychological variables including emotion (Mc Farland and Ross, 1983), self-esteem (Brockner and Guare, 1983), expectations (Phares, 1957), and motivation (Rotter, 1954), as well as behaviour and learning (Wasserman, 1990). This may in part be due to the lack of a reliable method to experimentally manipulate attribution, which also can fulfil the task demands of cognitive neuroscience studies.

Heider (1958), developing ideas derived from classical philosophy and Gestalt psychology (Foersterling, 2001), formulated the concept of causal attribution, which is defined as the process of arriving at perceived causes of someone's own and other people's behaviour (Weiner, 1992). Insights gained from attribution theory have been applied to a variety of research domains such as health psychology (Taylor, 1983) and personality styles (Rotter, 1954) as well as clinical (Foersterling, 1988), educational (Weiner, 1979), and organisational psychology (Folkes, 1990). Since the approach we developed addresses beliefs about someone's own failure and success, we will focus on attributions in the achievement context.

Weiner's analysis of achievement behaviour (Weiner et al., 1971), based on the work of Heider (1958), Kelly (1967), and Rotter (1954) remains an influential model (Foersterling, 2001). In European societies four causes are most frequently used to account for success or failure; ability, effort, difficulty, and chance (e.g. Elig and Frieze, 1979; Weiner, 1992). Based on previous research using multidimensional scaling and factor analysis (Passer et al., 1978), Weiner (1985) developed a classification of perceived causes of effects according to a 2 × 2 × 2 orthogonal taxonomy with a bipolar continuum for each dimension; internal/external causality (the location of causality), stability/instability (the temporal nature of the cause) and controllability/uncontrollability (the degree of volitional control). Weiner suggested that aptitude attributions are

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internal, stable, and uncontrollable, whereas attributions to task characteristics are external, stable, and uncontrollable. Furthermore, he suggested that temporary effort ascriptions are internal, unstable, and controllable, while chance attributions are external, unstable, and uncontrollable.

1.1. *Manipulation of attribution*

How stimulus information influences causal thinking, depends on the information (causes) individuals are provided with and the degree to which the possible causes co-vary with the effect (Kelly, 1967; Foersterling, 2001). Based on numerous studies (e.g. Phares, 1957; Weiner and Kulka, 1970; Meyer, 1973) Weiner (1992) concluded that consistency (variance of the effect over circumstances), consensus (variance of the effect between people), perceived task characteristics and task structure were the main determinants of whether success or failure are ascribed to either the individual's ability or the task's difficulty. Weiner and Kulka (1970), examining the effect of consensus information on causality ascriptions, provided participants with information about the task outcome of a fictitious person and the social norm (rate of success of a large sample). The results demonstrated that increased consistency between the performance of the fictitious person and other individuals led to more external attributions (such as task characteristics). However, the importance of consensus information remains uncertain (for a discussion see Foersterling, 2001).

Providing different information with the intention to modify ascriptions has been investigated since the early phase of attribution theory. Phares (1957) first changed outcome ascriptions by introducing an ambiguous task, in which success was attributed to either chance or ability. The 'skill' instruction described the task as being difficult but solvable dependent on the participant's ability whereas the 'chance' instruction described the task as being extremely difficult and solvable only at pure chance level. Phares's results demonstrated that expectancy of success or failure was closely linked to 'skill' and 'chance' beliefs. A number of studies have shown that changes in expectancy correlate with the stability dimension, independently of the location of causality dimension (e.g. Meyer, 1973). Furthermore, changes in the stability more than the locus of causality dimension influence performance quality (Meyer, 1973). However, the use of gambling tasks (a classical paradigm for chance dependent tasks) has been described as problematic for inducing causality ascriptions; individuals tend to misconceive gambling tasks as being ability dependent, i.e. attribute them internally rather than externally (e.g. Wortman, 1975). In order to ensure that experimental manipulation of the locus of causality dimension has the desired effect and to avoid confounding this with the stability/instability dimension, changes in expectancy and performance should be equal for external and internal attributions.

Based on these experimental findings, manipulation of perceived causality has also been used in therapeutic approaches (for an overview see Foersterling, 1985, 1988). In a therapeutically oriented 'reattribution' approach Brockner and Guare (1983) investigated whether individuals with low self-esteem can improve task performance when causal ascriptions to task difficulty were introduced. They asked two groups of participants to work on an insolvable concept formation task. Before starting the task subjects in the experimental group were presented with fake information on the performance of 'previous subjects'. For the 'external group' the information described the task as relatively difficult, by showing that 'previous participants' did very poorly, whereas the task was described as relatively easy for the 'internal group'. Brockner and Guare could demonstrate that the information on social norms combined with that of task characteristics successfully modified the subject's attributions for task failure. In addition, as predicted, low self-esteem individuals improved their performance in the external manipulation group.

More recently, using the CDS-II (The revised Causal Dimension Scale, McAuley et al., 1992) questionnaire for manipulation check, Van Dyck and Homsma (2005) found that, although 93% of their participants recognized 'time pressure' as an obvious cause of errors, 19% attributed their performance failure to internal causes (e.g. 'not enough time for me') rather than to external ones. They assumed that even when people agree with an external cause, they might not necessarily form an external attribution. This highlights the problem of measuring attribution when only a 'concrete' cause is offered. To avoid this problem, Homsma et al. (2007) gave 'explicit instructions' in order to manipulate attribution. They told their subjects to think about possible causes for errors and to attribute them to internal, external, stable or unstable causes. Although subjects appeared to make attributions as expected, they might have, by being compliant, been following these instructions but not been truly generating these attributions.

1.2. *Cognitive neuroscience and attribution*

More recently, attribution has been investigated with neuroscience approaches (Liebermann et al., 2002; Blackwood et al., 2003; Harris et al., 2005). According to the causality of observed behaviour Liebermann et al. (2002) described a possible neural system that would underlie the dual process model of attribution. The authors distinguished between a reflective system and a reflexive system, which they postulated had a different neuroanatomical basis. In this model automatic initial dispositional attributions are produced by the reflexive system, whereas the reflective system is responsible for propositional thoughts; on the neural level the lateral temporal cortex, including the superior temporal sulcus (STS), parts of the temporal lobes, and the temporal poles (as part of the reflexive system) may be responsible for processing the information involved in dispositional attributions. To further investigate this model Harris et al. (2005), using fMRI and an experimental paradigm based on Kelley's attribution theory, found activity in the STS associated with person attributions (internal attribution of observed behaviour). The authors speculated that dispositional ascriptions of other people's behaviour might recruit parts of the neuronal circuits associated with "Theory of Mind".

However, whether ascriptions of someone's own behaviour activates the same neural circuits is uncertain, since no judgement of observed behaviour is required. There appears to be only one brain imaging study that investigated self ascriptions. Seeking to identify the neural systems involved in self serving biases (external attribution of negative events and internal attributions for positive events) and self responsibility, Blackwood et al. (2003) found activity in the left lateral cerebellar hemisphere, bilaterally in the pre-motor cortex, and the right lingual gyrus, when individuals reported internal attributions of experienced positive and negative events (self responsibility). In contrast, external attributions (ascribing effects to other people or outside causes) resulted in activation of the STS. That STS activity was found with external attributions is notable, since it supports the involvement of the STS in ascribing events to other people's dispositions or responsibility. The authors therefore assumed that the brain activity associated with self responsibility is related to 'simpler internal models of goal-directed action'. In addition, self serving vs. non-self serving biases yielded different brain activation patterns. The authors used ten statements of the IPSAQ (Internal, Personal, and Situational Attribution Questionnaire) to which participants responded to during the fMRI scan. However, the authors realized that the methodology resulted in a small number of described external attributions and a limited variety of ascriptions in some subjects resulting in several data sets being discarded.

Very few studies have investigated attribution with neuroscience methodologies. This may in part be due to the problem of high-level social cognition eliciting brain activation patterns that reflect a number of confounding variables, limiting the interpretation of the findings (Kok et al., 2006). Cacioppo et al. (2003) stated that when using subtractive techniques for imaging data, the interpretations of the subtracted images depends on the different task demands between the experimental and the control condition which may not reflect a single psychological variable. In addition, Cacioppo et al. note that using the subtractive method requires that the information processing is linear and additive which may not hold for complex social phenomena.

1.3. *The present study*

The aim of the present study was to develop an experimental design that enables both, the manipulation of causal ascriptions of one's own behaviour in 'a real-life achievement context', and its concurrent application with cognitive neuroscience methods, e.g. EEG or fMRI. We used a modified, speeded, arrowhead version of the Erikson Flanker Task (Erikson and Erikson, 1974). Since a Flanker task has often been used in electrophysiological research (e.g. Fiehler et al., 2005) task demands for electroencephalogram (EEG) data analysis are given, i.e. a large number of erroneous and correct trials, under all conditions, allow for the use of averaging techniques. Although fMRI does not have the same time resolution as electrophysiological responses, a Flanker Task can still be utilised in imaging studies. Ullsperger and Cramon (2001) developed an interleaved design for image acquisition, to improve temporal resolution with a flanker task. We hypothesised that a Flanker Task could be adapted so that it would be perceived as either an "easy concentration test" or as a "difficult task" resulting in different attributions for success or failure providing an adequate task structure to modify causal ascriptions (Weiner, 1992).

Based on Fiehler et al. (2005) we developed an adaptive algorithm, aiming to deliver negative (for late and error responses) and positive feedback at about chance level. This was required to achieve equal performance levels in the different groups and to correct for individual differences. Additionally, we expected instructions (such as; the task is easy vs. difficult) to be quite plausible in an ambiguous situation when experience of previous success and failure during the task was balanced. In the study a two block design has been used with the manipulative instruction given after the first block. Due to this design task conditions were kept equivalent and the first blocks could serve as control conditions since no information on the nature of the task had been provided to either group. In order to avoid confounding expectancy and performance influences (Meyer, 1973; Phares, 1957) instructions that aimed to provoke ability ascription for failure (internal-stable-uncontrollable) in one group and difficulty attribution for failure (external-stable-uncontrollable) in the other group were used. Following Brockner and Guare (1983) and Weiner (1992) consensus information and task characteristic information were different between the two instructions, whereas instructions were otherwise equal. We hypothesised that under this arrangement a stable attribution manipulation could be achieved over a large number of trials with performance held at chance level by the adaptive algorithm without subjects being aware of this. Additionally, we expected differences in attribution exclusively on the locus of causality dimension. Explicitly, individuals who would receive the 'easy concentration test' information were expected to attribute errors to their own performance, whereas those persuaded that the task is difficult were expected to attribute mistakes to task characteristics.

2. Material and methods

2.1. *Participants*

Twenty-four, healthy, students (female, mean age 25.13) who gave informed consent participated in this study. All participants had no history of neurological or psychiatric diseases and had normal or corrected to normal vision.

2.2. *Task*

An adapted, speeded arrowhead version of the Erikson Flanker Task (Erikson and Erikson, 1974) was employed using an in-house presentation software, running under Linux. Within each trial five white arrowheads were presented in a horizontal row against a black screen. The arrowheads consisted of two arms both 2 cm in length. The viewing distance of approximately 60 cm resulted in a 2° visual angle horizontally and vertically. Participants were instructed to concentrate on the central arrowhead and to ignore the other ones. To increase task difficulty a target stimulus could either point left, right, up, or down, whereas the distracters varied in pointing left or right. Participants had to respond with their left index finger if the target arrowhead pointed left or up and with their right index finger if the target pointed right or down. There were compatible (i.e. the flanker indicated the same response as the central target) and incompatible (i.e. the flanker indicated a conflict response to the central target) trials. Compatible and incompatible trials were presented in pseudo-random order having the same frequency. Subjects were informed that they could make two types of error, either pressing the wrong button or responding too slowly. With a delay of 1000 ms following each target onset one of three different symbols in the centre of the screen indicated the current performance. Green plus signs indicated correct responses in due courses and red minus signs incorrect ones. When the response was out of time a message appeared on screen 650 ms after stimulus onset saying, the response was tardy, please respond faster next time. This message was followed by a blue minus sign. There were two blocks, each of 350 trials, with a break of various lengths in between.

2.3. *Adaptive algorithm*

As already mentioned an adaptive algorithm (Fiehler et al., 2005) was used in order to achieve a negative feedback (error responses and time outs) rate of about chance level (50%). According to this algorithm a response time value (RV) was dynamically adjusted within the range of 200–800 ms in steps of 100 ms always after 40 consecutive trials dependent on the subject's current performance value (PV). This performance value in turn was counted up or down by 1 for a positive or negative feedback respectively, with each single trial. Initially, RV was set to 500 ms and PV to 0. With each 40th trial RV was decreased by 100 ms if PV was greater than 20 and RV greater than 200 ms in order to enforce a higher rate of negative feedback, otherwise RV was increased by 100 ms; in either case PV was then set to zero. For an illustration of the algorithm see Appendix A. Full programming details

Table 1

Mean proportions of correct, error, and ‘time out’ responses for compatible, incompatible, and all trials separated for blocks (standard errors in parentheses)

	Compatible trials		Incompatible trials		All Trials	
	Response rate (%)	Response time (ms)	Response rate (%)	Response Time (ms)	Response rate (ms)	Response time (ms)
Performance data of the first block						
Prior Instruction A						
Correct	66.87 (6.64)	347.23 (50.71)	41.49 (10.03)	429.73 (31.10)	54.2 (5.19)	*
Error	6.52 (3.32)	*	19.18 (15.66)	317.95 (57.19)	12.91 (9.1)	*
Time out	26.52 (8.71)	*	39.25 (13.34)	*	32.89 (10.67)	*
Prior Instruction B						
Correct	65.1 (7.13)	350.46 (52.13)	42.23 (8.47)	433.07 (35.04)	53.64 (3.82)	*
Error	7.15 (4.48)	*	21.68 (13.54)	324.83 (68.35)	4.43 (8.01)	*
Time out	27.74 (9.82)	*	36.00 (8.49)	*	31.92 (8.97)	*
Performance data of the second block						
Post Instruction A						
Correct	73.36 (8.29)	321.55 (40.70)	43.55 (10.27)	394.2 (35.97)	58.51 (5.26)	*
Error	5.30 (2.30)	*	23.83 (17.20)	286.08 (37.44)	14.51 (8.65)	*
Time out	21.34 (8.65)	*	32.62 (11.52)	*	27.00 (9.39)	*
Post Instruction B						
Correct	70.75 (7.47)	314.97 (48.90)	42.20 (9.67)	376.38 (56.08)	56.46 (4.31)	*
Error	6.77 (6.13)	*	26.36 (18.18)	285.54 (49.26)	16.75 (11.42)	*
Time out	22.48 (9.82)	*	31.44 (11.15)	*	26.97 (9.90)	*

Note: In most participants the number of errors on congruent trials was too small for further analysis.

for the flanker task and this algorithm are available from the authors.

2.4. *Experimental manipulation of attribution*

Subjects were randomly assigned to two groups. Both groups received the same standard task instructions before starting the experiment with a first block as a set of ‘practice trials’. Thereafter, one of the two following instructions was given verbally in German language (Comments relevant to attribution are shown in italics):

Instruction A: ‘The practice part is over and I will now tell you the experiment’s purpose. *This is an ability test*. We will measure your ability for attention and concentration during the next block. As you must have realized during the practice part, *the test is quite easy*. You *simply have to press the left or the right button. People make very few errors*, because it is so easy.’

Instruction B: ‘The practice part is over and I will now tell you the experiment’s purpose. This is a *so called Flanker Task*. This task is deliberately designed in a way that people commit many errors. As you must have realized during the practice part, the *task is quite difficult. You have a very short time to respond, People make lots of errors*, because it is so difficult.’

With instruction A, a fake picture of a “concentration test” was also presented before starting the second block.

At the end of the second block participants were asked to complete an adapted version of the IE-SV-F (Fragebogen zur Erfassung von internalen/externalen und stabilen/variablen Attributionen in Abhaengigkeit von Erfolg und Misserfolg, Dorrman and Hinsch, 1983; ‘Questionnaire for capturing internal/external and stable/instable attributions depending on success and failure’). The questionnaire allowed the measurement of the locus as well as the stability dimensions in success and failure situations during the flanker task. We adopted nine statements to the flanker task situation, maintaining the original responses (e.g. “I think the failure was due to a lack of my ability.”). This resulted in a 36 item questionnaire with a scale of 1–4 for each item (“Applies in no way” to “Applies completely”). At the end of the experiment participants were debriefed and informed about the true purpose of the study.

3. Results

3.1. *Behavioural data*

Table 1 shows reaction time (RT) and performance data for each group pre and post instruction. RT was defined as the time between stimulus onset and the button press.

As can be seen in Table 1 performance effects typical for flanker tasks in general were found with no significant differences between the groups. Independent of the instructions, participants committed more errors on incompatible trials in both blocks.

Using a three-way repeated measures ANOVA with the between subject factor Instruction (2 levels: Instruction A or B), and three within factors: Response (2 levels: correct and incorrect), Block (2 levels: block 1 and block 2), and Compatibility (2 levels: compatible and incompatible) significant interactions Compatibility × Response (F (2, 21) = 71.6, $p < 0.000$) and Response × Block (F (2, 21) = 12.5, $p < 0.000$) were found. The latter possibly indicated practicing over time. No interaction with the between subject factor Instruction reached the level of significance even after setting alpha to 0.2. Thus, the different instructions did not lead to differences in accuracy.

Table 2

Mean proportions of correct, error, and ‘time out’ responses, separated by instructions (standard errors in parentheses)

	All trials (40) Response rate (%)	Incompatible trials Response time (ms)
Post Instruction A		
Correct	75.00 (15.25)	290.80 (49.50)
Error	15.75 (12.75)	417.50 (50.90)
Time out	9.50 (9.00)	*
Post Instruction B		
Correct	69.75 (11.25)	299.3 (82.80)
Error	19.75 (11.75)	401.5 (59.30)
Time out	10.50 (9.00)	*

The first 40 trials of the second block were chosen, since the effect of the adaptive algorithm was not yet present. Note, that response times were only computed for incompatible trials, because the number of errors on compatible trials was insufficient for further analysis.

Typical effects were observed for reaction time. RTs were longer for incompatible than for compatible trials. This observation was statistically confirmed using a repeated measure ANOVA for correct responses with the 'within' factors Compatibility and Block, and Instruction as a between subject factor. It revealed a significant main effect for Compatibility ($F(1, 20) = 205.13$, $p < 0.000$). The ANOVA for RTs of incompatible trials only, again with the 'within'-factors Response and Block, and Instruction as a between subject factor, resulted in a significant main effect of factor Response ($F(1, 20) = 40.26$, $p < 0.000$). That demonstrated that errors were associated with shorter reaction times. Again the main effect of the factor Block ($F(1, 20) = 309.33$, $p < 0.000$) indicated practicing effects over blocks. Importantly, no significant interaction was found ascribable to Instruction, which emphasized that RT was not influenced by the instructions.

However, since performance might have been influenced by the balanced control of negative/positive feedback, the two groups were compared additionally on the performance and RT data of the first 40 trials of the second block (immediately after instruction A or B was given). As noted earlier, the first adjustment of the response window occurred after the 40th trial. Therefore, responses to these 40 initial trials were not influenced by the adaptive algorithm.

As can be seen in Table 2, there were no differences in performance and RT ascribable to the different instructions. This was again confirmed by ANOVAs using only these first 40 trials. The analysis on performance data did not yield a significant interaction Instruction × Response ($F(2, 19) = .392$, $p = .618$). Equally no significant interaction Instruction × Response ($F(20, 1) = 1.385$, $p = .253$) was found for RT data, demonstrating that the different instructions had no influence in this respect.

Additionally, as can be seen in Table 1 when taking all negative feedback trials (error and late response) into account, the adaptive algorithm indeed led to approximately 50% negative feedbacks in all conditions. And, importantly, after debriefing at the end of the experiment, all participants reported that they had not been aware of the effects of this control algorithm.

3.2. Manipulation check

For each attribution factor; chance, ability, difficulty and effort, an average score of corresponding items of the adapted IE-SV-F (see above) was calculated for each subject individually.

Mann–Whitney *U*-test statistics yielded significant differences depending on the instructions. As shown in Table 3 Instruction A provoked significantly more failure attributions to 'ability' than Instruction B ($U = 26.00$, $Z = -2.69$, $p < .01$). In addition, Instruction B led to fewer failure attributions to 'task difficulty' than Instruction A ($U = 12.00$, $Z = -3.49$, $p < .000$). There were no significant differences on the dimension 'stability' (chance and effort attributions) and in 'success' attributions. It is noticeable, that the group differences were highly significant in comparison to previous manipulations of causality (e.g. Brockner and Guare, 1983; Van Dyck and Homsma, 2005; Homsma et al., 2007) Following Newcombe (2006) method for calculating effect sizes and confidence intervals for non-parametric group comparisons, we found a large effect for failure attributions to ability ($U = 26.00$, $Z = -2.69$, $p < .01$, effect-size $\theta = .18$ with a confidence interval of [.07; .41]) and a very large one for failure attributions to task difficulty ($U = 12.00$, $Z = -3.49$, $p < .000$, $\theta = .08$ [.02; .29]).

Table 3
Mann–Whitney *U*-test statistics for the attribution questionnaire data

Average scores	Condition					
	Instruction A			Instruction B		
	n	Mean rank	*n*	Mean rank	*U*	*Z*
Success ability	12	9.83	12	15.17	40.00	−1.89
Success difficulty	12	12.96	12	12.04	66.50	−.33
Success chance	12	10.75	12	14.25	70.00	−.12
Success effort	12	12.67	12	12.33	51.00	−1.24
Failure ability	12	16.33	12	8.67	26.00	−2.70**
Failure difficulty	12	7.50	12	17.50	12.00	−3.45**
Failure chance	12	9.88	12	15.13	58.50	−.79
Failure effort	12	11.38	12	13.63	40.50	−1.87

$p < .05$; $^{**}p < .01$.

4. Discussion

In this study an adapted version of the Erikson Flanker Task was developed and tested where the individual error-levels were kept at approximately 50%. Using this method the investigation of state attributions and emotional consequences using neuroscience methods would be possible. The task was administered to two groups two times. After an initial block, members of one group were instructed that the task is an easy concentration test, while those of the other group received the instruction that the task is quite difficult.

While typical effects for flanker task performance in general were found, it could furthermore be shown that the two groups differed significantly in their evaluation of the perceived causes of errors depending on the instruction they received. Since a manipulation check was administrated after the participants finished the second block, we can assume that the experimental manipulation of attribution remained stable over the 350 trials of the second block. It should be noted that previous attempts to manipulate achievement attribution were not capable of being used for numerous trials (e.g. Feather, 1967; Brockner and Guare, 1983; Van Dyck and Homsma, 2005; Homsma et al., 2007). The paradigm used in the present study changed attributions over numerous trials and therefore would be able to facilitate the acquisition of event related brain potentials (ERP). Furthermore, it has been demonstrated that the groups solely differed in the locus dimension and not within the stability dimension. According to social psychology (e.g. Phares, 1957; Meyer, 1973) we concluded that there were no differences in expectations between the groups. In addition, according to the self reports and based on the subjects performance (error and time out responses) and reaction times, no differences were found on the effort dimension. Since performance was controlled by the adaptive algorithm we additionally compared performance data and reaction times of the first 40 trials of the second block, in order to avoid a possible bias due to the adaptive control. Again, no performance and reaction time differences were found indicating that the two groups did not differ in effort. This experimental paradigm, therefore, successfully evoked isolated differences in the locus of causality dimension by suppression of potential confounds, which is essential for an unambiguous interpretation of imaging data in cognitive neuroscience research (Cacioppo et al., 2003; Kok et al., 2006). Changes in attribution, however, would be expected to influence subsequent emotional responses (Weiner, 1992).

However, our approach to the experimental manipulation of attribution could not be used in a within group experimental design since it would not be possible to persuade an individual that the same task was on one occasion easy and on another difficult. Although a between group design is generally less powerful than a within group comparison, our method produced a very large behavioural effect size with the possibility of a similarly large effect at the neural level. Furthermore, our approach as well as techniques previously used to manipulate attribution are not compatible with counter balanced experimental designs, since manipulation of attribution can only be produced either immediately, or after an initial trial when the same task is involved (e.g. Feather, 1967; Brockner and Guare, 1983; Van Dyck and Homsma, 2005; Homsma et al., 2007). With our paradigm learning effects were shown not to differ between groups during the second block, which excluded at least one possible confound. It, therefore, appeared unlikely that the two groups would have differed significantly in any other time dependent variable, and thus differences in the behavioural data and possibly in brain activity during the second block should reflect modification of attribution.

The Erikson Flanker Task, as a speeded reaction time task, has often been used to investigate event related potentials, associated with committing errors (e.g. Gehring et al., 1993). Approximately 80 ms after committing an error, a negative deflection in the ongoing EEG can be observed. This event related potential (ERP) has maximal amplitudes at fronto-central electrode sites and has been referred to as Error Related Negativity (ERN). Following negative feedback, an equal distributed component can be observed on frontal–central recording sites approximately between 250 and 350 ms after feedback onset, named the, Feedback Related Negativity (fERN) (Holroyed and Coles, 2002). Numerous studies have found associations of the ERN amplitude with emotion and motivation (e.g. Hajack et al., 2004; Luu et al., 2000), however, no study has yet investigated error related ERP-components and attribution.

Using our approach the neural basis of actor ascriptions in the achievement context and their emotional consequences could be further investigated. According to Weiner (1985) depending on the perceived cause of an event specific emotions can be elicited. Numerous studies have provided evidence for the coherence between causality ascriptions and emotions (i.e. McFarland and Ross, 1982; Weiner, 1997). Feather (1967) demonstrated that failure in a task that is perceived as being ability dependent is rated more aversive and unattractive for individuals than failure in a chance dependent task. Additionally, moral emotions, such as shame or guilt, associated with causal ascriptions (for an overview see Weiner, 1992) could be further explored. Using the methodology described, an “on-line” elicitation of attribution related affects could be achieved, since during the experiment participants actually feel the emotions associated with different attributions in the simulated achievement situation. This might avoid previously described limitations of using affective pictures to provoke affects, which always requires self reports of the current emotional experience (Amodio and Frith, 2006). Moral emotions (guilt and embarrassment) have been investigated with fMRI by presenting sentences containing embarrassing, guilt, or neutral information. Importantly, both emotions were accompanied by activity in the medial prefrontal cortex and the left posterior superior temporal sulcus. However, STS activation was also observed with the ascription of events to other people’s dispositions or responsibility (Blackwood et al., 2003; Harris et al., 2005). Following Weiner (1985) guilt is associated with self responsibility as reflected in internal attributions. We suspect that further research, using our approach could help to elucidate the neural basis of moral emotions clarifying these conflicting findings.

Appendix A

Algorithm 1 lists the pseudocode for the Erikson Flanker Task and the adaptive algorithm. This algorithm was designed to achieve equal performance for the different groups and to correct for individual differences. Furthermore, the error rate was held at approximately 50% throughout each block.

Algorithm 1. Adaptive Erikson Task()

```
Require: itemlist /* array of items */
Set: $rv = 500$ /* initial response time value */
Set: $pv = 0$ /* initial performance value */
foreach item in itemlist do
    /* item presentation*/
    Present: itemlist[item]
    rt <= collectReactiontime() /* in ms */
    answer <= collectAnswer()
    /* feedback and adaption of performance value*/
    if (rt <= rv & answer == 'correct') then
        Present: positiveFeedback()
        Set: $pv = pv + 1$
    elseif (rt <= rv & answer == 'wrong') then
        Present: negativeFeedback()
        Set: $pv = pv - 1$
    else
        Present: timeoutFeedback()
        Set: $pv = pv - 1$
    end if
    /* evaluation of subject's performance */
    if (item mod(40) = 0) then
        if ($pv >= 20$ & $rv > 200$) then
            /* decrease response time value */
            Set: $rv = rv – 100$
        elseif ($pv < 20$ & $rv < 800$) then
            /* increase response time value */
            Set: $rv = rv + 100$
        end if
        Set: $pv = 0$ /* reset performance value */
    endif
end foreach
```

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