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Embodied empathy towards patients with stroke

Rui Watanabe[1,2,3], Birgitta Paranko[1,2], Lauri Nummenmaa[1,2,4]

[1] Turku PET Centre, University of Turku, Finland

[2] Turku PET Centre, Turku University Hospital, Turku, Finland

[3] Tokyo Metropolitan University, Tokyo, Japan

[4] Department of Psychology and Speech-Language Pathology, University of Turku, Turku, Finland

Address Correspondence to:
Rui Watanabe
Turku PET Centre c/o Turku University Hospital
FI-20520 Turku, Finland
Email: wtnb_cnb@tmu.ac.jp

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Abstract

Empathy toward patients with stroke may facilitate helping. Because stroke patients' physical disabilities impact multiple body parts causing context-dependent difficulties during everyday activities, observers need to continuously monitor these difficulties to update their empathic responses. Here we tested whether observers embody the stroke patients' motor difficulties during everyday locomotory task, and whether time-variable empathetic responses are coupled with helping motivation,

Participants viewed videos of patients with stroke or healthy individuals walking and stepping over obstacles. In study 1, we measured participants' bodily sensations, emotions felt while viewing the videos, and emotions attributed to the patient in the video. In study 2, participants provided continuously rated empathy and willingness to help while viewing the same videos. Participants attributed strong limb sensations to the patients' stroke-affected body parts, and mirrored these sensations also in their own bodies. They also experienced and attributed stronger negative emotional experiences to the patients than healthy controls. Time-varying ratings revealed that empathy and willingness to help toward patients were engaged even before the difficulties in locomotion were evident. Empathy and willingness to help ratings also increased continuously over time and were strongly coupled.

These findings suggest that empathy toward patients with stroke is embodied, through sensations specific to the stroke-affected limbs and bodily regions. Empathy and helping motivation are rapidly engaged, dynamically updated as situations unfold, and tightly coupled over time. Overall these results suggest an embodied basis of empathy toward patients with stroke and its close relationship with helping motivation.

Keywords: Empathy, help, stroke, emotion, body, sensations

Introduction

Empathizing with patients with stroke benefits them across the multiple domains, including improvements in physical function, reducing psychological burden, and enhanced social participation (Christensen et al., 2019; Truitt et al., 2023; Mullin et al., 2026). These patients often face difficulties in everyday actions due to their limited mobility, thus empathy from the general public would be an important means for motivating help and providing the necessary support for the patients (McKevitt et al., 2011; Kruithof et al., 2013; Zawawi et al., 2020)

Studies on empathy toward patients with stroke have highlighted particularly the role of affective process in feeling patients' difficulties or negative emotions rather than cognitive empathic process (Hicks et al., 2022) (Watanabe & Kuruma, 2025). Affective empathy involves emotional responses that include intuitive sharing of others' emotions, potentially mediated through one's own bodily states, whereas cognitive empathy involves reflectively understanding others' thoughts and experience (Shamay-Tsoory, 2011; Bernhardt & Singer, 2012). Previous studies have found that observing others' pain or injury evokes distress accompanied with vicarious somatic sensations in the observer's body parts corresponding with those in the target of empathy. For example, seeing an individual receiving a painful injection to their hand can elicit negative emotions and pain-like sensations in the observer's own hand and. Similarly observing another person with an injured leg can evoke uncomfortable sensations in the observer's leg together accompanied by some negative emotions (Osborn & Derbyshire, 2010; Voisin et al., 2011). Such embodied empathic responses are foundational in motivating helping through empathetic concern directed to the individual experiencing distress such as those suffering from physical impairments caused by a stroke. However, little is known about how these individuals i) perceive the distress of patients with stroke and ii) represent it in their own somatomotor systems.

Patients with stroke experience dynamically unfolding difficulties during everyday situations. The patients may, for example, be proficient in walking on a flat surfaces, but experience severe difficulties when climbing even a small set of stairs. Consequently, it is imperative to consider how observers' empathic responses evolve over time in relation to the changing conditions of patients with stroke, which may shape appropriate help for them. Previous studies have found that empathic responses unfold over time during social interactions with others. When seeing and listening to others, individuals continuously update their empathic responses in response to changes in the others' emotional expressions (Zaki et al., 2009). Willingness to help is also sensitive to the level of others' distress, as observers offer more help when they perceive others experiencing greater distress (Chen et al., 2024). Brain imaging studies further suggest that empathy may drive helping behavior through recruiting partially overlapping brain regions during empathic processing and helping behavior (Decety et al., 2016; Bellucci et al., 2020). Together, these findings indicate that empathy and willingness to help are linked and that they may also co-evolve over time when conditions change, such as when an individual walking with support suddenly trips over thus requiring even more intensive help. Yet, such coevolution of empathy and willingness to help remains poorly understood.

Previous studies on empathy in clinical settings have rarely focused on the embodied and dynamically evolving nature of empathic responses. Most studies have relied on ' self-reported responses or linguistic analyses and using stroke- or disability-related narrative vignettes or role-play simulations (Iezzoni & Long-Bellil, 2012; Yang et al., 2018; Alawafi et al., 2023). However, the physical difficulties experienced by patients with stroke are complex, as motor impairments are distributed across multiple body regions and challenges continuously change over time during everyday activities such as walking. To empathize with these physical challenges, observers may need to represent these difficulties through their own bodily states and dynamically update such empathic responses as the situation unfolds.

The current study

Here we mapped the bodily responses to and temporal evolution of empathy towards and willingness to help patients with stroke. Participants viewed videos of healthy individuals and patients with stroke navigating a typical urban sidewalk and stepping over an obstacle. We first measured bodily responses, emotions felt while viewing the videos, and emotions attributed to the person in the video. In a separate experiment the participants provided moment-to-moment evaluations of their empathetic responses and willingness to help the individual in the video. This approach allowed us to examine how observers' bodily sensations mirror the somatomotor experiences of patients with stroke, by identifying where in their own bodies the observers felt sensations and where they attributed perceived sensations to patients. Given that patients' difficulties unfold moment-to-moment in real-life situations, we could also examine how observers update their empathic and helping responses in relation to changing situational demands. The observers reported strong limbs sensations corresponding to patients' affected body parts, both in their own bodies and when attributing sensations to patients. Time-varying ratings further revealed that empathic responses and willingness to help toward patients with stroke were engaged even before the onset of more challenging phase, increased over time, and were strongly coupled.

Study 1

Materials and Methods

In Study 1, we measured what emotions participants perceived the patients with stroke to experience in difficult locomotory situations (perceived condition) and what emotions they felt themselves while viewing the patients (felt condition). Two hundred participants were recruited via Prolific online platform (https://www.prolific.com/). Half were randomized to the perceived condition and half to the felt condition. Data from one participant from each group were excluded due to technical issues (e.g., network-related disruptions). This resulted in final samples of 99 participants per group (perceived conditions: mean age = 33.86 ± 9.86 years; felt conditions: mean age = 31.55 ± 8.79 years). All participants reported no history of physical or mental disabilities, neurological, or psychiatric disorders.

Stimuli

The video stimuli featured patients with stroke walking in a realistic, everyday setting (Figure 1). The stimuli depicted them navigating a typical urban sidewalk and stepping over an obstacle. This is one of the most representative challenges faced by patients with stroke in their daily lives: stair negotiation is among the most physically demanding tasks for them, and the inability to perform this task can restrict independent living (Alzahrani et al., 2009; Ridgway et al., 2015).

Figure 1. Four conditions of movie clips featuring patients with stroke (top) and healthy controls (bottom) walking and stepping over stairs of two heights (high or low).

Videos were recorded from seven patients with stroke (three women and four men; mean age 53.3 ± 10.1 years), including three with left and four with right hemiplegia. All were in the chronic phase post-stroke and showed moderate-to-severe lower-limb motor impairment (Lower Extremity Fugl-Meyer Assessment: 9-21/34) (Fugl-Meyer et al., 1975; Gladstone et al., 2002). All scored 6 on the walking and stair-use items of the Functional Independence Measure, indicating independent mobility with personal canes, which were also used during video recording (Linacre et al., 1994).

In each video, patients with stroke walked approximately five meters, turned left, and stepped over the obstacle. No instructions were provided regarding walking style or speed to preserve natural performance. Two obstacle heights were used: High, difficult step (25cm) and Low, easy step (15cm), and each patient completed both conditions, resulting in two videos per patient. Patients reported that obstacles around 15 cm were commonly encountered in daily life, whereas 25-cm obstacles were more challenging and less frequently attempted. The same task was recorded in seven age-matched individuals without disabilities (three women and four men; mean age = 54.1 ± 13.5 years) as control stimuli. The final stimulus set consisted of four conditions: Stroke-High, Stroke-Low, Control-High, and Control-Low, each containing seven videos (Figure 1). Mean video durations for these conditions were 17.65 ± 3.42 s, 12.17 ± 3.82 s, 5.47 ± 0.57 s, and 5.30 ± 0.40 s, respectively.

Bodily Sensation Mapping

BSM data were collected with the emBODY-tool, which measures topographic distribution of bodily sensations by coloring the body regions where people feel sensations (Nummenmaa et al., 2014). Participants viewed an empty silhouette and colored body regions where they felt sensations by pressing the mouse button and dragging the cursor. Each region was recorded in a binary manner as either colored or uncolored.

Procedure

Date were collected via the online experiment platform Gorilla (https://app.gorilla.sc) (Figure 2).

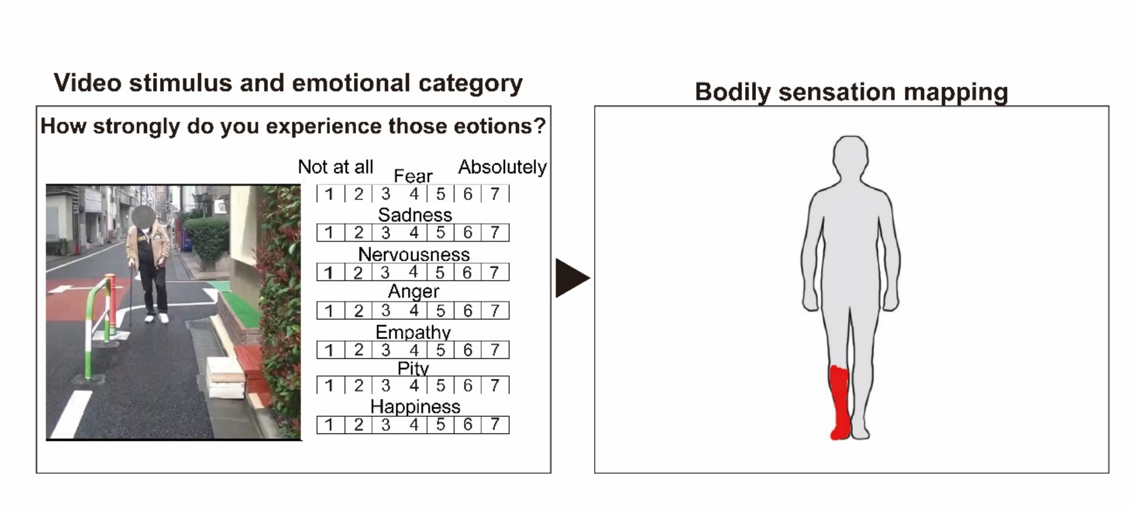


Figure 2. Sample trial flow from the perceived emotion, showing the video stimulus and emotion-rating interface (left) and the bodily sensation mapping task (right).

Each trial began with a fixation cross presented for 1.5 seconds, followed by an instruction (“How strongly does the person experience those emotions” for perceived emotions or “How strongly do you experience those emotions?” for felt emotions). Participants then viewed the video stimulus and rated seven emotional categories (Anger, Empathy, Fear, Happiness, Nervousness, Pity, and Sadness) on a 7-point scale (0 = Not at all and 7 = Absolutely). The order of the emotional categories displayed on the screen was randomized across trials. After completing the ratings, participants proceeded to the BSM task.

In the BSM task, participants viewed an empty human body silhouette with the instruction: “Color the regions of the body where the person in the video might have felt something while walking and clearing the step” (perceived sensations) or “Color the body areas where you felt something while watching the video” (felt sensations). After finishing the coloring task, participants proceeded to the next trial. Each participant completed 28 trials, including seven trials for each of the four experimental conditions.

Measurement of empathic ability

After completing all trials, participants completed the Interpersonal Reactivity Index (IRI) (Davis, 1980), widely used self-report questionnaire assessing empathic traits. It consists of four subscales: Perspective Taking (PT), Fantasy (FS), Empathic Concern (EC), and Personal Distress (PD). In this study, we used scores from these subscales to examine how individual differences in empathic traits influenced empathic responses.

Data analysis

All data were analyzed using MATLAB 2024a (Mathworks Inc., Sherborn, MA).

BSMs data analysis

BSMs were screened for anomalous painting (e.g., scribbling), and coloring outside the body silhouette was masked out. For each participant, BSMs were averaged within each condition, separately for perceived and felt sensations. Pixel-wise mass univariate t-tests against zero were then conducted for each experimental condition, producing group-level statistical t-maps reflecting significant bodily sensations for Stroke-High, Stroke-Low, Control-High, and Control-Low.

We then compared Stroke (Stroke-High + Stroke-Low) versus Control (Control-High + Control-Low) conditions to identify heightened bodily sensations in the Stroke condition, and additionally contrasted Stroke-related bodily sensations between the perceived and felt conditions. Spearman correlation analyses were also conducted between pixelwise BSM activation and each IRI subscale score separately for each condition-subscale combination. Statistical significance for all BSMs analyses was set at $p < .05$ (False Discovery Rate (FDR)-corrected at the pixelwise level).

Emotion category ratings

Wilcoxon signed-rank tests were used to compare median emotion ratings across four experimental condition pairs within perceived and felt conditions: Stroke-High versus Stroke-Low, Stroke-High versus Control-High, Stroke-Low versus Control-Low, and Control-High versus Control-Low. Mann-Whitney U tests were further conducted to compare perceived and felt emotion ratings for each condition and emotional categories. All p values were FDR corrected, with the significance set at $p < .05$.

Associations between emotion ratings and traits empathy

Spearman's rank correlation analyses were performed between emotion ratings and IRI subscale scores separately for the perceived and felt conditions (See Supplementary Methods and Results).

Results

BSM

Figure 3 shows the condition-wise BSMs for perceived and felt sensations, together with the regions whose sensations were dependent on individual differences in empathy dimensions. In the perceived sensations condition, bodily sensations were primarily localized to the upper and lower limbs for the stroke patient videos, whereas in the felt sensations condition, the sensations were distributed across the whole body. Spearman correlation analysis demonstrated that participants with higher EC scores on the IRI reported stronger chest sensations for the felt sensations in both Stroke-High and Stroke-Low. No other significant correlations were observed in the Control conditions or for the perceived sensations.

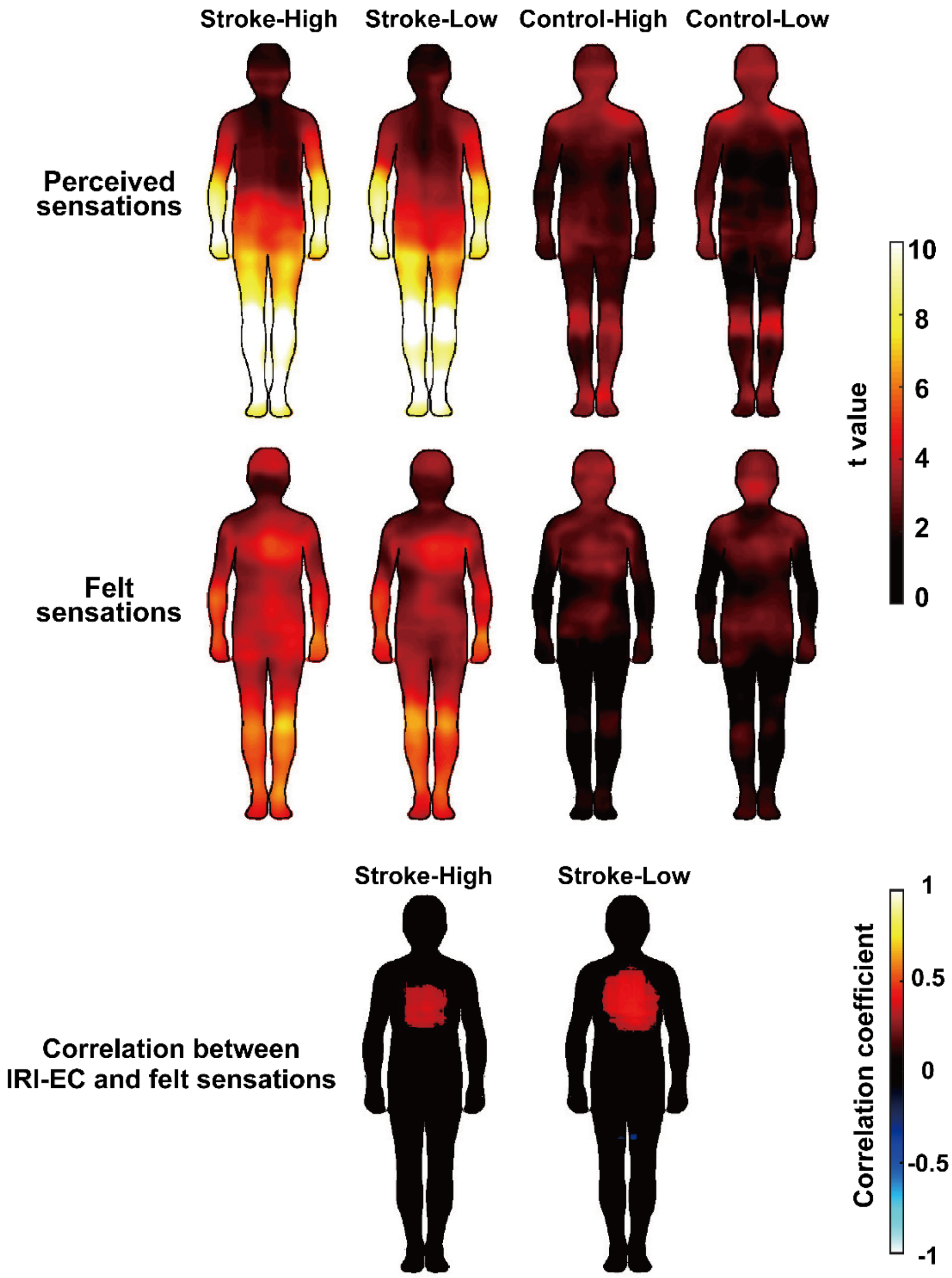


Figure 3. Bodily sensations felt while watching the video stimuli in each condition (felt sensations, top) and sensations perceived in the person in the video (perceived sensations, middle). Each map represents the condition-wise mean (thresholded at $p < .05$, FDR corrected). The bottom panel shows regions where bodily sensations were positively correlated with IRI-EC scores in the Stroke-High and Stroke-Low conditions for felt sensations. The data are thresholded at $p < .05$, FDR corrected. The colourbar indicates the t-statistic range.

Contrasting the BSMs for the Stroke versus Control conditions (Stroke-High + Low vs. Control-High + Low) revealed significantly stronger sensations, particularly in the upper and lower limbs, in the perceived condition. In the felt condition, stronger sensations were also observed in the limbs and extended to the entire body. Comparing stroke-related bodily sensations (Stroke (High+Low) > Control (High+Low)) between the perceived and felt conditions revealed significantly stronger sensations in the upper and lower limbs in the perceived condition, whereas the felt condition elicited stronger sensations in the chest and head (Figure 4).

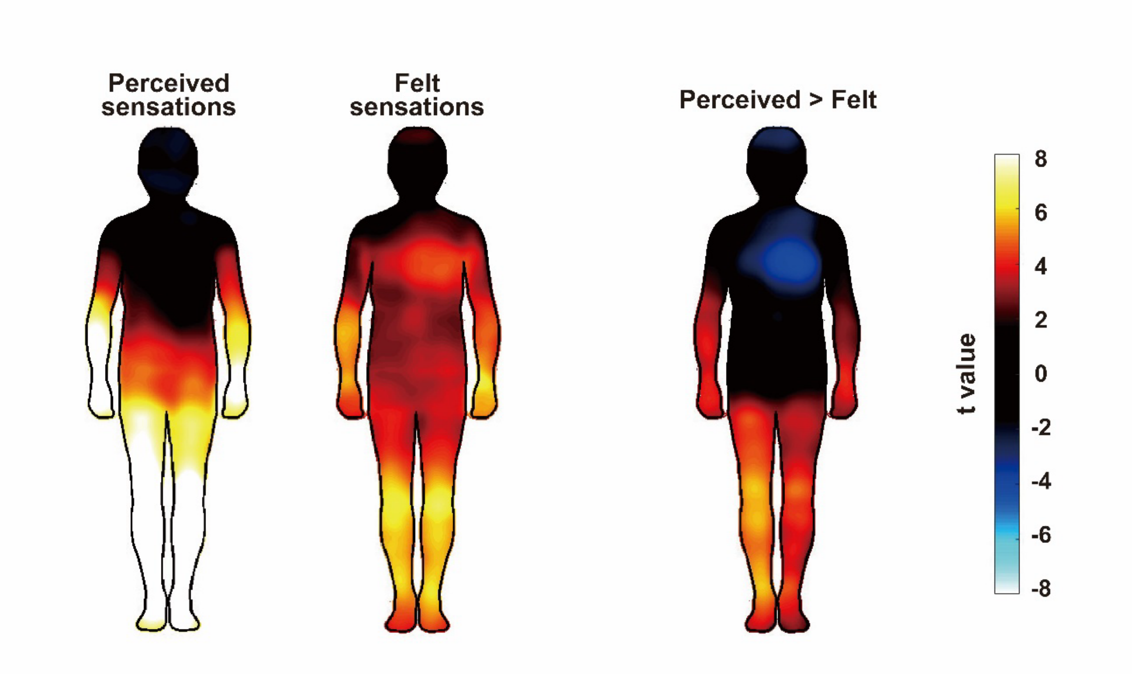


Figure 4. Bodily regions where perceived (left) and felt (middle) sensations were stronger in the Stroke versus Control conditions (high and low conditions combined). Rightmost figure shows regions the differences between perceived versus felt sensations was larger (hot colours) or smaller (cool colours) for the stroke versus control condition. The data arethresholded at $p < .05$, FDR corrected. The colourbar indicates the t-statistic range.

Emotion category ratings

Perceived and felt emotion category ratings (Anger, Fear, Nervousness, Happiness, Sadness, Empathy, and Pity) across the conditions are shown in Figure 5.

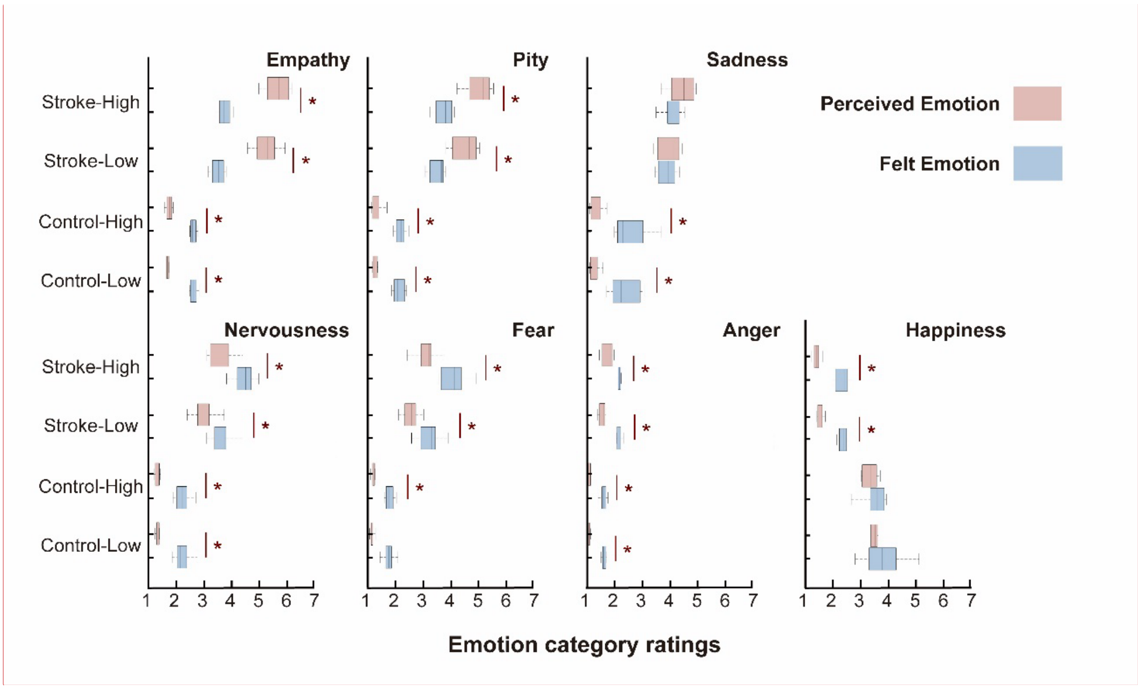


Figure 5. Distributions of perceived and felt emotion ratings. Asterisks indicate statistically significant ($p < 0.05$) differences between perceived and felt conditions.

Differences between perceived and felt emotions

We performed Mann-Whitney U tests with FDR correction ($p < .05$) to compare the median differences emotion ratings between perceived and felt emotions separately for each condition. For Anger, Fear, and Nervousness, ratings for felt emotions were significantly higher than for perceived emotions across all conditions. For Empathy and Pity, ratings for perceived emotions were significantly higher than for felt emotions in Stroke-High and Stroke-Low, whereas ratings for felt emotions were higher in Control-High and Control-Low (all $p < .05$). For Sadness, ratings for felt emotions in Control-High and Control-Low were significantly higher than for perceived emotions, while no significant differences were found for Stroke-High or Stroke-Low. For Happiness, ratings for felt emotions were significantly higher than for perceived emotions in Stroke-High and Stroke-Low (all $p < .05$) with no significant differences in Control-High or Control-Low (see Table S1 for full statistical results).

Emotion differences across conditions

We also performed Wilcoxon signed-rank tests with FDR correction ($p < .05$) to compare the median differences of each emotion category across the four conditions. Ratings for perceived emotions across all emotional categories were significantly higher in Stroke-

High than in both Stroke-Low and Control-High, and higher in Stroke-Low than Control-Low. No significant differences were observed between Control-High and Control-Low for each category.

For felt emotion, ratings for Anger, Sadness, and Happiness were significantly higher in Stroke-High than in Control-High, and in Stroke-Low than Control-Low. No significant differences were found between Stroke-High and Stroke-Low or between Control-High and Control-Low. For Fear, Nervousness, Empathy, and Pity, ratings for Stroke-High were significantly higher than for both Stroke-Low and Control-High, and Stroke-Low was significantly higher than Control-Low. No significant differences emerged between Control-High and Controls-Low (see Table S2 for full statistical results).

Study 2

Materials and Methods

Study 2 investigated the temporal dynamics of empathy and willingness to help, focusing on how these responses evolve and interact over time. This study included two dynamic rating conditions: empathy and willingness to help. Fifty independent participants were recruited for each condition via the Gorilla platform (https://app.gorilla.sc) using Prolific. Due to unexpected PC issues (e.g., network-related disruptions) or failure to follow task instructions, data from two participants in empathy and four in willingness to help were excluded. The final analyses included 48 participants for empathy (mean age = 35.97 ± 11.28 years) and 46 for willingness to help (mean age = 28.83 ± 7.05 years). Exclusion criteria were histories of physical or mental disabilities and neurological or psychiatric disorders.

Procedure

We presented participants with the same videos as previously, but this time acquired dynamic (i.e., time-varying) ratings. Each trial began with a 3-s fixation cross followed by presentation of a video stimulus. Participants continuously rated patients' difficulty as an indicator of empathy toward patients "How difficult is it for the person to walk and clear the step?" in the empathy condition or helping motivation toward them "How much would you help them if they asked for your help, even if you were in a hurry" in the willingness to help condition using a slider ranging from 0 to 100. In the empathy condition, ratings ranged from "Not at all" to "Extremely difficult", whereas in the willingness to help condition they ranged from “Not at all” to “Absolutely help” (Figure 6a).

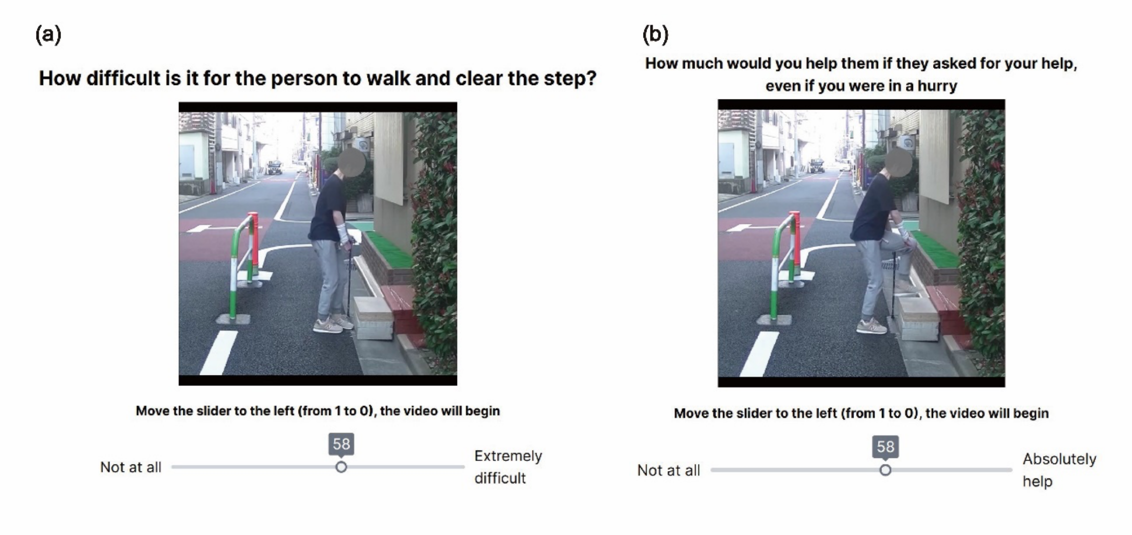


Figure 6. Experimental setup.

Before each video began, the slider was initially set to 1 (near the leftmost position). Once the participant moved the slider to the far left (i.e., 0), the video began. Participants were instructed to adjust the slider in real time, at any time during the video, in response to the instruction. This thus yielded time-series ratings of empathy and willingness to help for each video. Each video stimulus was presented once, and the order of presentation was fully randomized within each experiment. Each participant completed 28 trials across the four experimental conditions.

Measurement empathic ability

As in Study 1, after completing all trials, participants were asked to complete the Independent Reactivity Index (IRI) (Davis, 1980).

Data analysis

Temporal dynamics of empathy and willingness to help

Because video durations varied across stimuli, time-series ratings were resampled to a common temporal scale ranging from 0 to 100% of video duration prior to analysis. This resulted in one value per normalized time point for each video, enabling direct comparisons across videos in terms of relative time. To map the temporal evolution of empathy and willingness to help, we conducted time-point-wise t-tests separately. For each rating type, we examined the effect of stroke using four pairwise comparisons:

Stroke-High vs. Control-High, Stroke-High vs. Stroke-Low, Stroke-Low vs. Control-Low and Control-High vs. Control-Low. For each comparison, the significance level was set at $p < .05$ with FDR correction.

Temporal coupling between empathy and willingness to help

We conducted a sliding window Pearson's correlation analysis to assess the time-varying relationship between empathy and willingness to help ratings, separately for each condition (Stroke-High, Stroke-Low, Control-High, and Control-Low). A window size of 20 time points with a 1–point step size was used, resulting in 81 overlapping windows that covered the entire time series from 1 to 100%. P-values from each window were FDR-corrected for multiple comparisons, with a significance threshold set at $p < .05$.

Differential temporal changes in empathy and willingness to help

Sliding-window slope analyses were additionally conducted to examine whether the rates of change differed between empathy and willingness to help ratings over time (see Supplementary Methods and Results).

Influence of empathic traits on empathy and willingness to help over time

Linear mixed-effects models were further conducted to examine how individual differences in empathic traits influenced time-series ratings across conditions (see Supplementary Methods and Results).

Results

Time-series plots of empathy and willingness to help across the four experimental conditions are shown in Figure 7. For the stroke patient videos, both empathy and willingness to help began ramping up almost immediately after the video onset, rising steadily throughout the video presentation. The onset of obstacle negotiation occurred at variable time points across videos within each condition, with ranges of approximately 49%-74% in the Stroke conditions and 48%-65% in the Control conditions (means: Stroke-High 63.1%, Stroke-Low 60.4%, Control-High 56.7%, Control-Low 52.5%).

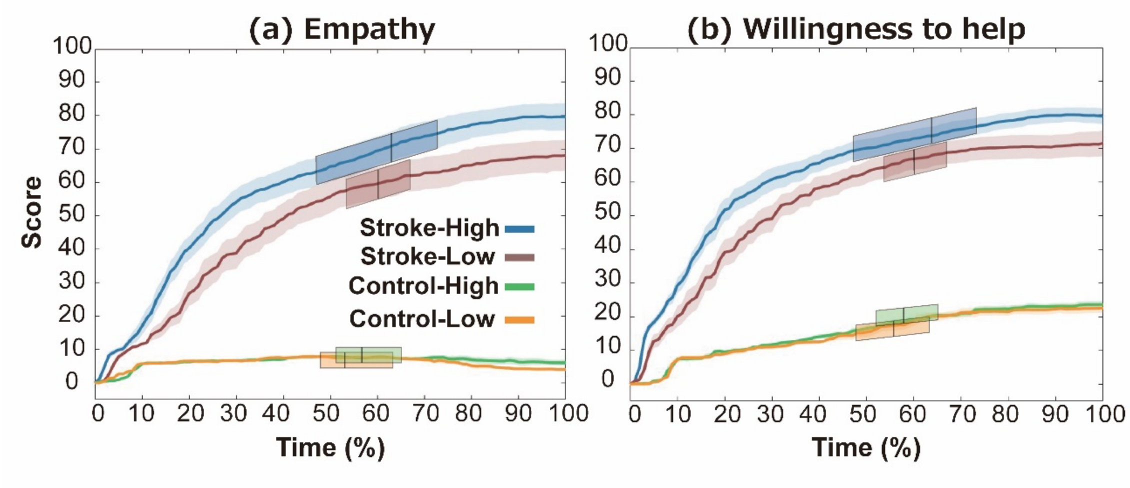


Figure 7. Time series plots of (a) empathy ratings and (b) willingness-to-help ratings across experimental conditions. Data are shown as means ±SEM. Shaded boxes indicate the time window of climbing onset across videos; vertical lines show the mean onset time.

Temporal differences in empathy and willingness to help across conditions

To assess whether the willingness to help and empathy evolved differently towards the patients with stroke versus controls, we conducted pointwise t-tests at each of the 100 time points (1-100%). FDR correction was applied within each comparison to control for multiple comparisons ($q < .05$) (See Supplementary Figure 2 and 3). In the empathy condition, ratings in Stroke-High were significantly higher than those in Control-High nearly the entire time course (2-100%), with the peak difference at 98% ($d = 6.45$). Stroke-Low elicited significantly higher ratings than Control-Low from early in the trial (4-100%), with the peak difference at 94% ($d = 4.98$). Stroke-High showed significantly higher ratings than Stroke-Low across most time points (2-3, 11-100%), with the strongest effect at 18% ($d = 0.78$), whereas no significant differences were observed between Control-High and Control-Low at any time point. Across comparisons, peak differences appeared almost immediately after participants observed the individual stepping over the obstacle, corresponding to the most demanding phase except for Stroke-High vs. Stroke-Low comparison.

Willingness to help ratings were significantly greater in Stroke-High than in Control-High across nearly the entire time course (2-100%), with the peak difference at 88% ($d = 2.48$). Stroke-Low showed significantly higher ratings than Control-Low across almost all time points (2-100%), with the maximum effect at 58% ($d = 1.98$). In contrast, no significant differences were observed between Stroke-High and Stroke-Low or between Control-High and Control-Low across the time series. The strongest differences were observed immediately after clearing the obstacle in Stroke-High vs. Control-High. In Stroke-Low vs. Control-Low, the peak effect occurred during the phase when the individuals were climbing the obstacle.

Temporal coupling between empathy and willingness to help

To examine the time-varying relationship between empathy and willingness to help, we performed Pearson's correlation analysis comparing ratings for the same conditions across two experiments (see Supplementary Results and Figure S4). Empathy and willingness to help ratings were strongly coupled throughout the time course in the stroke conditions: both empathy and willingness to help ratings consistently increased from the beginning to the end of the videos. In the Control conditions, the relationship between empathy and willingness to help became more variable over time, showing strong positive coupling until the midpoint followed by the negative correlations.

We further compared the rate of change in empathy and willingness to help ratings over time using a sliding window slope analysis (see Supplementary Results and Figure S5). In the Stroke conditions, the rates of change were not significantly different across most of the time course, with only transient dissociations emerging during middle or later time windows. In contrast, in the Control conditions, willingness to help ratings showed consistently steeper increases than empathy ratings across the time course.

Discussion

Our main finding was that empathy toward patients with stroke is embodied and dynamically linked to helping motivation in natural situations where the patients have difficulties. Participants accurately perceived bodily sensations in the patients, particularly in limb regions corresponding to motor difficulties, but also reported experiencing the corresponding sensations in their own body. These sensations were also associated with individual differences in emotional empathy. The patients were also perceived to experience more negative emotions than controls and participants felt stronger negative emotions themselves when watching the patients versus controls. Using time-varying ratings we further demonstrated that empathy and willingness to help toward patients with stroke increased consistently throughout the trials, indicating that the more we see someone being in need of help, the stronger the empathy and the urge to help become. Altogether these findings suggest that empathy toward patients with stroke is embodied in both self-and patient-oriented emotional responses, and dynamically linked to helping motivation, while also indicating that helping responses may not always align with empathic responses depending on the context.

Embodied and emotional responses toward patients with stroke

We observed distinct patterns of embodied empathy toward controls and patients with stroke. Perceived sensations were localized to the upper and lower limbs in the patients, corresponding to motor difficulties, whereas felt sensations in observers extended beyond the limbs to include the chest. Direct comparisons revealed that perceived sensations were concentrated in the limbs, while felt sensations were more pronounced in the chest. Thus, observers represented patients' walking difficulties by experiencing themselves in patients' bodies and by experiencing them in their own bodies. As patients with stroke often experience significant motor impairments, particularly in their paralyzed limbs (Mayo et al., 1999; Langhorne et al., 2011; Lin et al., 2021), and the patients in the videos also reported such limb-related difficulties, observers' responses likely reflect empathetic processing of patients' physical difficulties. Additional chest sensations in the felt condition further suggest broader affective engagement, consistent with evidence linking emotional experiences to increased sensations in the chest region (Nummenmaa et al., 2014). This interpretation is further supported by the observed positive association between chest sensations and empathic concern (EC), which reflects the affective dimension of empathy.

Emotion ratings showed that participants perceived patients with stroke to experience more negative emotions than controls and also reported stronger negative emotions themselves when watching the patients versus controls. Given that the patients in the videos were indeed experiencing difficulties while walking, these perceptions appear to align with the challenges they faced. This is consistent with our previous findings showing that observers perceived stroke patients to experience difficulties when moving their paralyzed hand (Watanabe et al., 2020). Moreover, participants' own negative emotional responses are consistent with prior evidence that observing others in distress elicits emotional stress in the observer as part of empathic processing (Eisenberg, 1994; Jackson et al., 2005). Together, these findings indicate that, in real-life situations, observers not only recognize patients with stroke facing emotional challenges but also experience corresponding self-related emotions as empathic responses.

Negative emotions felt by participants were also stronger than those attributed to patients. This is consistent with Decety and Lamm (2006), who suggest that adopting a detached or an objective perspective can attenuate the intensity of perceived emotions to prevent excessive distress-related arousal. In contrast, an imagine-self perspective, as in the felt condition, engages stronger affective responses and greater personal distress than an other-oriented perspective, as it involves representing the situations as one's own (Batson et al., 1997; Lamm, Batson, et al., 2007). Accordingly, the perceived condition may reflect more conservative evaluations of patients' emotional states to prevent excessive arousal, while the felt condition suggests that observers nevertheless experience more intense self-oriented negative emotions.

Embodied and affective mechanism of empathy toward patients with stroke

The bodily sensation maps indicated that empathy toward patients with stroke is embodied and associated with empathic emotional responses. According to the Perception-Action Model, perceiving another person's state automatically activates corresponding representations in the observer's body, generating associated somatic responses (Preston, 2002). Such shared representation also engages the affective system, resulting in shared emotional responses (Lamm & Majdandzic, 2015; Ferrari & Coudé, 2018). Accordingly, the difficulties of patients may be mapped onto observers' bodily representations, allowing them to experience these difficulties through their own bodies. This motor mapping may in turn engage affective representations, prompting empathic responses. Through this shared representation process, observers may not only perceive patients' emotion but also experience stronger self-oriented negative emotions. The more pronounced chest sensations in the felt condition may reflect such increased emotional responses and may be further enhanced by observers' higher empathic concern.

Dynamic coupling between empathy and willingness to help

Empathy and willingness to help for the patients with stroke began ramping up shortly after observers view them and continuously increased even before the onset of obstacle negotiation, irrespective of obstacle height. Moreover, these ratings were higher than those for controls across the time course. This suggests that observers rapidly detect and respond to patients' motor difficulties even during less demanding phases, rather than only during overtly challenging phases. This is supported by previous study showing that strong empathic responses are elicited by observing subtle movements performed with a paralyzed hand by stroke patients (Watanabe et al., 2022). Our findings also suggest that, while observing the patients with stroke walking, participants may engage with them moment by moment, continuously facilitating empathic responses. Previous studies have suggested that observers' representations can be updated through increased familiarity or experience, thereby facilitating empathic responses toward targets (Langford et al., 2006; Zaki et al., 2009; Watanabe et a., 2022). Moreover, given that empathy is considered to be a driver of helping behavior, perceiving patients' difficulties may progressively motivate observers to support them over time (de Waal & Preston, 2017; Sato et al., 2015). Together, our findings suggest that the longer observers see patients with stroke being in need of help, the stronger their empathy and willingness to help become.

For patients with stroke, empathy and willingness to help were tightly coupled over time, with both responses increasing across the time course. Moreover, the change rates in empathy and willingness to help ratings were not significantly different across most of the time course, indicating that these responses evolved similarly as the situation unfolded. These patterns are consistent with previous findings showing that that perceiving others' distress is associated with helping motivation and may promote prosocial behavior (Eisenberg & Miller, 1987; FeldmanHall et al., 2015; Sato et al., 2015). These findings suggest that empathy toward patients with stroke is dynamically shaped according to real-life situations and supports helping motivation.

In contrast, for the controls, the two responses were positively correlated at the beginning but became negatively correlated from the obstacle phase, with willingness to help increasing while empathy slightly decreased. Sliding window slope analysis also revealed that willingness to help increased more rapidly than empathy across all time windows. However, given the relatively low intensity and variability in the ratings in the Control conditions, these findings should be interpreted cautiously because correlations can become sensitive to small fluctuations and may not fully reflect the relationship between empathy and helping motivation. Nevertheless, prior studies suggest that moral motivations, such as a principle of care or moral identity, can contribute to helping when empathic responses are relatively weak (McCauley et al., 2024). Helping motivation in the Control conditions may have been grounded in not only by empathic responses but also by moral motivations.

Clinical implications

Observers represent stroke patients' bodily difficulties through their own bodily sensations and perceived patients' sensations. Thus, fostering empathy may benefit from incorporating physical or visually grounded experiences rather than just relying solely on abstract or vignette-based approaches. Given that empathy and helping motivation evolve dynamically and that these responses are sensitive to even less serious need for help, exposure to dynamic and situations including variable contexts may facilitate empathic engagement with patients' physical struggles. Finally, while fostering empathy may enhance helping motivation, promoting trait perspective taking may be particularly beneficial, as it can increase helping while preventing excessive emotional distress in observers.

Limitations

Our experimental task focused on affective empathy toward patients with stroke, such as intuitive and emotional processes. However, empathy also includes cognitive empathy associated with more contextually grounded and analytical responses that capture patients' everyday difficulties. In addition, they often have severe upper-limb impairments that limit daily activities. To further elucidate empathy mechanisms, future studies should incorporate more context-rich, hand-related tasks reflecting daily life.

Conclusions

We conclude that empathy toward patients with stroke is embodied, with observers representing patients' physical challenges through their own bodily sensations, including both perceived and self-related sensations. These somatomotor representations are linked with emotional responses, indicating that empathic processing involves both bodily and affective components. Empathic responses are engaged rapidly, dynamically updated as the situation unfolds, and tightly coupled with helping motivation. Altogether, these findings reveal how empathy toward patients with stroke is constructed through embodied representations, develops over time, and relates to helping behavior in everyday situations.

Supplementary Materials

Study1

Supplementary Methods

Associations between emotion ratings and traits empathy

We investigated each relationship between emotion category ratings and IRI subscale scores (EC, PT, PD and, FS) for each condition using Spearman's rank correlation, separately for the perceived and felt conditions. This approach allowed us to examine the associations for each specific emotion-IRI subscale pair of interest. For each correlation test, the significance level was set at $p < .05$.

Supplementary Results

Associations between emotion ratings and traits empathy

To examine the relationship between emotion category ratings and IRI subscale scores (EC, PT, PD and, FS) for each condition, we performed Spearman's rank correlation tests for perceived and felt emotions (see Supplementary Figure 1). Here, we highlight the significant associations most relevant to empathic traits. For perceived emotions, no significant correlations were observed between ratings in the Stroke conditions and EC or PT scores, although some significant correlations emerged in the Control conditions. In contrast, for felt emotions, ratings in the Stroke-High and Stroke-Low conditions for several emotion categories (Empathy, Pity, and Sad) showed significant positive correlations with EC and PT scores. In addition, Fear ratings in Stroke-High and Stroke-Low were positively correlated with EC scores, and Nervous ratings in Stroke-Low were positively correlated with EC scores.

Study2

Supplementary Methods

Differential temporal changes in empathy and willingness to help

We performed a sliding window slope analysis on empathy and willingness to help ratings, separately for each condition (Stroke-High, Stroke-Low, Control-High, and Control-Low). This analysis quantified how steeply ratings increased or decreased within local time segments, allowing us to examine whether the rate of change differed between empathy and wiliness to help ratings over time. We used a window size of 20 time points with a 1-point step size, covering the full range of normalized time points from 1% to 100% thus resulting in 81 overlapping windows. For each window, we fitted a linear regression to each participant's data to estimate the local slope, reflecting how sharply the ratings changed within that segment. The mean slopes were then statistically compared across datasets. P-values from each window were FDR-corrected for multiple comparisons, with a significance threshold set at $p < .05$.

Influence of empathic traits on empathy and willingness to help over time

To investigate how individual differences in IRI-based empathic traits influence time-series ratings across conditions, we conducted linear mixed-effects models. The dependent variable was the time-series rating of empathy or willingness to help. The models included Time (0 to 100), Condition (Stroke-High, Stroke-Low, Control-High, and Control-Low), and the IRI subscale scores (PT, EC, PD, and FS) as fixed effects, along with all two-way and three-way interaction terms (e.g., Time × Trait, Condition × Trait, Time × Condition × Trait). A random intercept for each participant was included to account for inter-individual variability. All predictors were mean-centered prior to modeling. Separate models were run for each IRI subscale. Significant interactions were followed up with condition-wise models to further examine trait-specific effects. The significant threshold for all fixed effects was set at $p < .05$.

Supplementary Results

Temporal coupling between empathy and willingness to help

To examine the time-varying relationship between empathy and willingness to help, we performed Pearson's correlation analysis comparing ratings for the same conditions across two experiments (Figure S4).

In the Stroke-High condition, we observed significant time-varying correlations between the two types of ratings across all time windows (mean ± SD = 0.97 ± 0.05; peak $r = 1.00$ at the 8^{th} window). Stroke-Low also demonstrated significant correlations across all time windows (mean ± SD = 0.99 ± 0.01; peak $r = 1.00$ at the 16^{th} window). In contrast, Control-High showed significant correlations in three phases: a positive correlation in windows 1-37, and negative correlations in windows 44-53 and 58-81. These phases corresponded to approximately 1-56%, 44-72% and 58-100% of the normalized time course respectively, (mean ± SD = 0.93 ± 0.08; peak $r = 0.99$ at the 1^{st} window; mean ±

SD =-0.71 ± 0.10; peak negative r =-0.81 at the 48th window; mean ± SD =-0.75 ± 0.18; peak negative r =-0.94 at the 73rd window, respectively). In the Control-Low condition, significant correlations were observed in two phases: a positive correlation in windows 1-34 and a negative correlation in windows 42-81. These phases corresponded to approximately 1-55% and 42-100% of the normalized time course respectively, (mean ± SD = 0.87 ± 0.10; peak r = 0.99 at the 5th window; mean ± SD =-0.81 ± 0.11; peak negative r =-0.92 at the 78th window, respectively).

In the Stroke conditions, both empathy and willingness to help ratings consistently increased from the beginning to end of the videos. In the Control conditions, both scores also commonly increased while the performers were walking and approaching the obstacles. However, once the performers began stepping over the obstacles, empathy ratings slightly decreased, whereas willingness to help continued to increase.

Temporal changes in empathy and willingness to help

To examine differences in the rate of change in time series ratings between empathy and willingness to help, we conducted a sliding window slope analysis within each condition (Figure S4). This analysis used 81 overlapping time windows covering the entire time series, with each window consisting of 20 time points. FDR correction ($p < .05$) was applied to the p-values for each window to determine statistically significant differences in slope.

In the Stroke-High condition, slopes for empathy were significantly higher than those for willingness to help during windows 43 –46 (mean slope difference ± SE = 0.19 ± 0.01; peak = 0.21 at window 46), corresponding to approximately 43%–65% of the normalized time course (see Figure 7 for the location within the time-series ratings). The Stroke-Low condition also showed significantly higher slopes for empathy than for willingness to help during windows 69–76 (mean slope difference ± SE = 0.18 ± 0.01; peak = 0.20 at window 72), corresponding to approximately 69%–95% of the normalized time course. In contrast, the Control-High condition demonstrated significantly lower slopes for empathy compared to willingness to help across all time series (window 1 –81) (mean slope difference ± SE =-0.19 ± 0.02; peak =-0.15 at window 28). In the Control-Low condition, slopes for empathy were significantly lower than those for willingness to help during two phases: windows 1 –21 (mean slope difference ± SE =-0.18 ± 0.06; peak =-0.11 at window 21; $p < .01$ for most windows, $p < .05$ in all) and window 31–81 (mean slope difference ± SE =-0.23 ± 0.06, peak =-0.1 at window 81), corresponding to approximately 1–40% and 31–100% of the normalized time course, respectively.

In the Stroke-High condition, empathy and willingness to help ratings exhibited broadly similar rates of change across most of the time course, with only transient dissociations around obstacle negotiation or during later phases. In contrast, in the Control conditions, willingness to help showed consistently steeper increases than empathy across most of the time course.

Influence of empathic traits on empathy and willingness to help over time

To examine how individual difference in empathic traits modulated temporal dynamics of empathy and willingness to help ratings, we fitted linear mixed-effects models separately for each rating type. Time, each IRI subscale, and experimental condition were entered as fixed effects, including all interactions (Time-series ratings = $Time_c$ × IRI $subscale_c$ × Condition), with subject included as a random intercept. Multicollinearity was first assessed for fixed-effect predictors using variance inflation factors (VIFs). All VIF values were ≤ 1.5, indicating negligible multicollinearity across all IRI subscales across empathy and willingness to help.

In the empathy condition, ratings increased over time in the Stroke-High condition (reference level; $\beta = 0.69$, $p < .05$), reflecting a positive effect of time at the mean level of the trait included in each model. This temporal increase was significantly attenuated in Stroke-Low ($\Delta\beta$ =-0.04), Control-High ($\Delta\beta$ =-0.67), and Control-Low ($\Delta\beta$ =-0.69) relative to Stroke-High (all ps < .05). Perspective taking (PT) significantly moderated the time course of empathy ratings across all conditions. Significant Time × PT interactions were observed in Stroke-High (β =-0.002), Stroke-Low (β =-0.007), Control-High (β =-0.008), and Control-Low (β =-0.009) (all ps < .05.), indicating that higher PT was associated with a reduced rate of increase in time-series ratings in all conditions (all ps < .05) (Figure S6a). Similarly, a significant Time × personal distress (PD) interaction was also observed in all conditions: Stroke-High (β = 0.01), Stroke-Low (β = 0.002), Control-High (β = 0.005), Control-Low (β = 0.007), reflecting that higher PD was associated with a steeper increase in ratings over time in all conditions (all ps < .05) (Figure S6b). This pattern contrasted with that of PT, which attenuated temporal increases.

For empathic concern (EC), significant Time × EC interactions were also observed across all conditions (Stroke-High: β = 0.005; Stroke-Low: β =-0.006; Control-High: β =-0.007;

Control-Low: β =-0.007; all ps < .05), although the direction of effects varied across conditions. In contrast, fantasy (FS) showed a significant interaction with Time only in the Stroke-Low condition (β =-0.01, p < .05). Unlike PT and PD, EC and FS did not exhibit consistent temporal modulation across conditions (See the full statistics in Table S3).

In the willingness to help condition, as with the empathy condition, ratings increased over time in Stroke-High as the reference condition (β = 0.58, p < .05), reflecting a positive effect of time at the mean level of the trait included in each model. These temporal dynamics were significantly modulated by the other conditions. Stroke-Low heightened this trend (Δβ =0.02), while Control-High (Δβ =-0.36), and Control-Low (Δβ =-0.36) attenuated the increase of ratings compared to Stroke-High (all ps < .05). In PT, a significant Time × PT interaction was observed in Stroke-Low (β = 0.005), Control-High (β =-0.008), Control-Low (β =-0.008) (all ps < .05). The observed effect of Stroke-High was not significant (β = 0.004, p = 0.11). Higher PT was associated with higher rate of increase in willingness to help time-series ratings in Stroke-Low but smaller increase rate in the Control conditions (Figure S7a). A significant Time × PD interaction was also observed in all conditions: Stroke-High (β =-0.005), Stroke-Low (β =-0.014), Control-High (β =-0.005), Control-Low (β =-0.003), reflecting that higher PD was associated with attenuated rate of increase in willingness to help ratings over time in all conditions (all ps < .05) (Figure S7b). For EC, significant Time × EC interaction was also found only in Stroke-High (β =-0.005, p < .05) but not in Stroke-Low (β = 0.003, p = .60), Control-High (β =-0.003, p = .22), Control-Low (β = 0.004, p = .22). Interaction between Time and FS was not significant in all conditions (See the full statistics in Table S4).

Together, higher PT attenuated increases in empathy ratings over time across all conditions, while enhancing increases in willingness to help ratings in the Stroke-Low condition but dampening that in Control conditions. In contrast, higher PD showed the opposite pattern, facilitating increases in empathy ratings while attenuating increases in willingness to help across all conditions.

Influence of empathic traits on empathy and willingness to help over time

To examine how individual difference in empathic traits, based on the IRI subscales, modulated temporal dynamics of empathy and willingness to help ratings, we fitted linear mixed-effects models separately for each rating type (see Supplementary Results and Figure S5 and S6). Overall, perspective taking (PT) and personal distress (PD) showed opposing effects: higher PT attenuated the rate of increase in empathy ratings over time but enhanced that in willingness to help ratings, whereas higher PD showed the opposite pattern, facilitating increases in empathy but dampening increases in willingness to help.

Supplementary Discussion

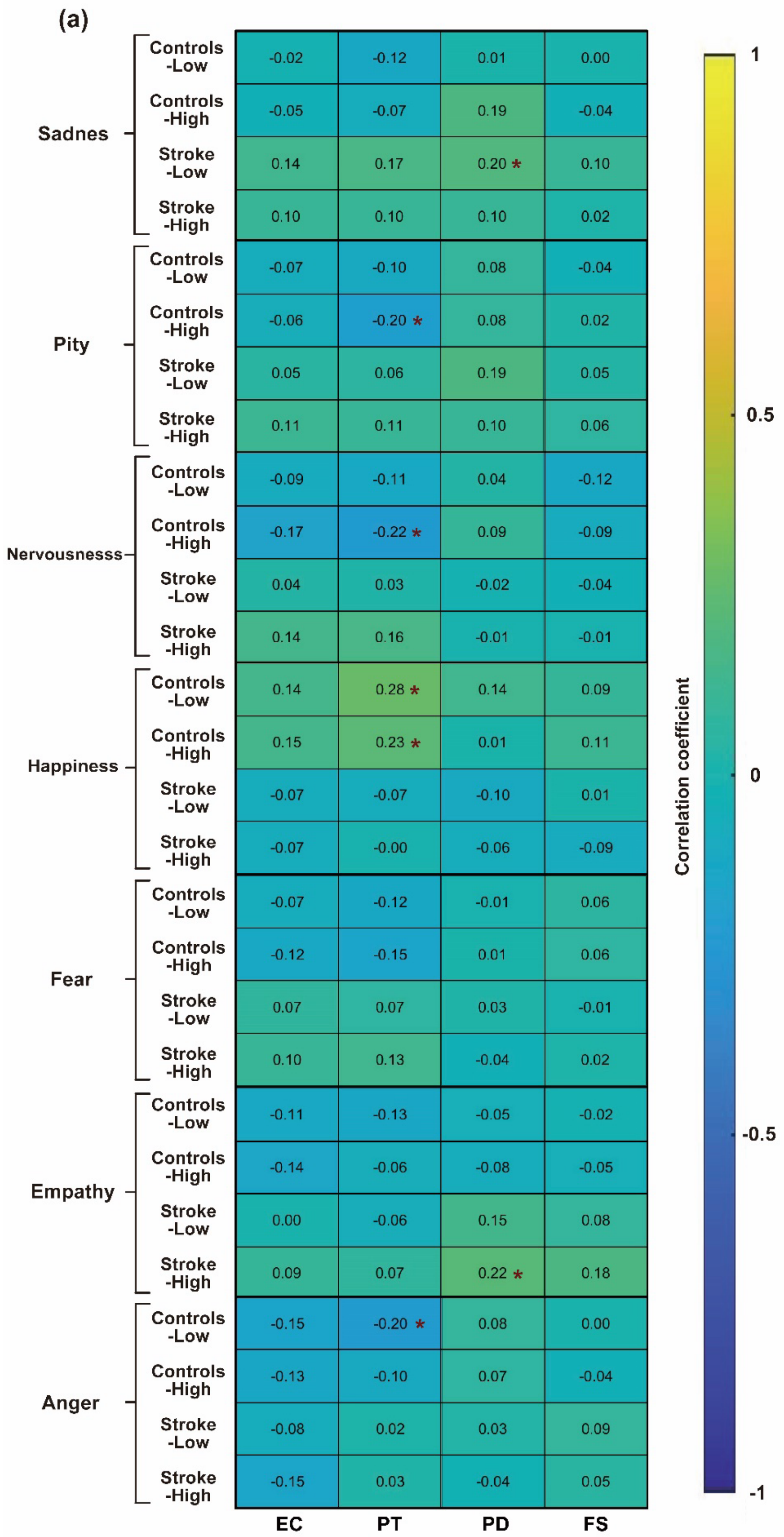
Influence of empathic traits on emotional category ratings

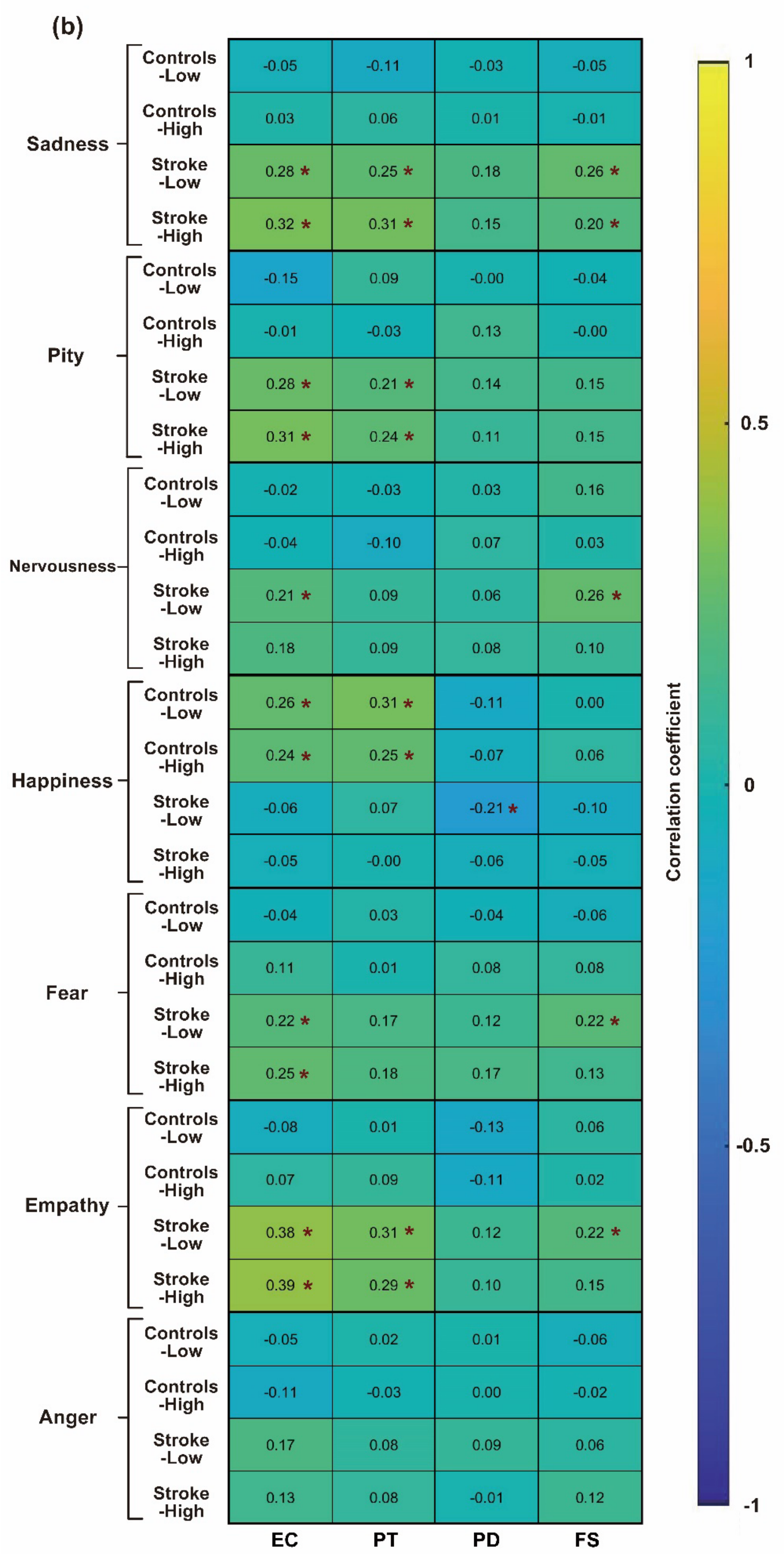
Empathic traits assessed by the IRI influenced both bodily sensations and emotional ratings only in the felt condition. Stronger chest sensations were associated with higher empathic concern (EC). Some negative emotions (e.g., fear) were associated with EC, whereas ratings in empathy-related emotions (e.g., empathy) were associated with both EC and perspective taking (PT). These findings align with previous work showing that individuals with higher empathic traits exhibit stronger self-oriented affective responses when observing others in distress (Lamm, Nusbaum, et al., 2007; Watanabe et al., 2020). As empathic concern reflects the affective dimension of empathy, it may influence self-oriented emotional resonance toward patients, as in the felt condition, whereas the perception of patients' difficulties may be less dependent on these traits. Because the chest sensations are linked with numerous emotional experiences (Nummenmaa et al., 2014), the chest-related sensations observed in the felt condition reflect affective components of empathic processing.

Influence of empathic traits on dynamic empathic responses

PT and personal distress (PD) influenced time course of ratings to patients with stroke in opposite ways. Higher PT attenuated increases in empathy but promoted willingness to help, whereas higher PD facilitated empathy but dampened helping motivation. Previous findings demonstrated that higher perspective taking trait regulates emotional responses, preventing the experience of excessive distress and facilitating altruistic motivation (Carlo, 1999; Decety & Lamm, 2006). In contrast, high personal distress evokes stronger empathic responses but is less likely to facilitate helping, as individuals focus on reducing their own discomfort elicited by others' distress (Eisenberg, 1994). Previous study on baseline mu-opioid receptor (MOR) availability, which reflects characteristics of pain and emotional regulation, have shown that lower MOR availability is associated with greater activity in pain-related brain regions when observing others' distress, suggesting that individuals with a low threshold for distress more vicariously respond to others' distress. In contrast, lower MOR availability is associated with reduced activity in brain regions related to perspective taking, potentially reflecting reduced prosocial tendencies (Karjalainen et al., 2017). Together, these findings suggest that time-varying empathic responses toward patients are shaped by sensitivity to other's distress, whereas helping motivation depends on perspective taking trait while regulating affective responses.

Supplementary Figures





(b)
Sadness
Pity
Nervousness
Happiness
Fear
Empathy
Anger
Controls -Low
Controls -High
Stroke -Low
Stroke -High
EC
PT
PD
FS
Sadness Controls-Low: -0.05 -0.11 -0.03 -0.05
Sadness Controls-High: 0.03 0.06 0.01 -0.01
Sadness Stroke-Low: 0.28 * 0.25 * 0.18 0.26 *
Sadness Stroke-High: 0.32 * 0.31 * 0.15 0.20 *
Pity Controls-Low: -0.15 0.09 -0.00 -0.04
Pity Controls-High: -0.01 -0.03 0.13 -0.00
Pity Stroke-Low: 0.28 * 0.21 * 0.14 0.15
Pity Stroke-High: 0.31 * 0.24 * 0.11 0.15
Nervousness Controls-Low: -0.02 -0.03 0.03 0.16
Nervousness Controls-High: -0.04 -0.10 0.07 0.03
Nervousness Stroke-Low: 0.21 * 0.09 0.06 0.26 *
Nervousness Stroke-High: 0.18 0.09 0.08 0.10
Happiness Controls-Low: 0.26 * 0.31 * -0.11 0.00
Happiness Controls-High: 0.24 * 0.25 * -0.07 0.06
Happiness Stroke-Low: -0.06 0.07 -0.21 * -0.10
Happiness Stroke-High: -0.05 -0.00 -0.06 -0.05
Fear Controls-Low: -0.04 0.03 -0.04 -0.06
Fear Controls-High: 0.11 0.01 0.08 0.08
Fear Stroke-Low: 0.22 * 0.17 0.12 0.22 *
Fear Stroke-High: 0.25 * 0.18 0.17 0.13
Empathy Controls-Low: -0.08 0.01 -0.13 0.06
Empathy Controls-High: 0.07 0.09 -0.11 0.02
Empathy Stroke-Low: 0.38 * 0.31 * 0.12 0.22 *
Empathy Stroke-High: 0.39 * 0.29 * 0.10 0.15
Anger Controls-Low: -0.05 0.02 0.01 -0.06
Anger Controls-High: -0.11 -0.03 0.00 -0.02
Anger Stroke-Low: 0.17 0.08 0.09 0.06
Anger Stroke-High: 0.13 0.08 -0.01 0.12
Correlation coefficient
1
0.5
0
-0.5
-1

Figure S1. Spearman correlation coefficients between emotion category ratings and IRI subscale scores (EC, PT, PD, FS) across conditions in (a) perceived emotion and (b) felt emotion. Asterisks indicate significant correlations ($p < .05$)

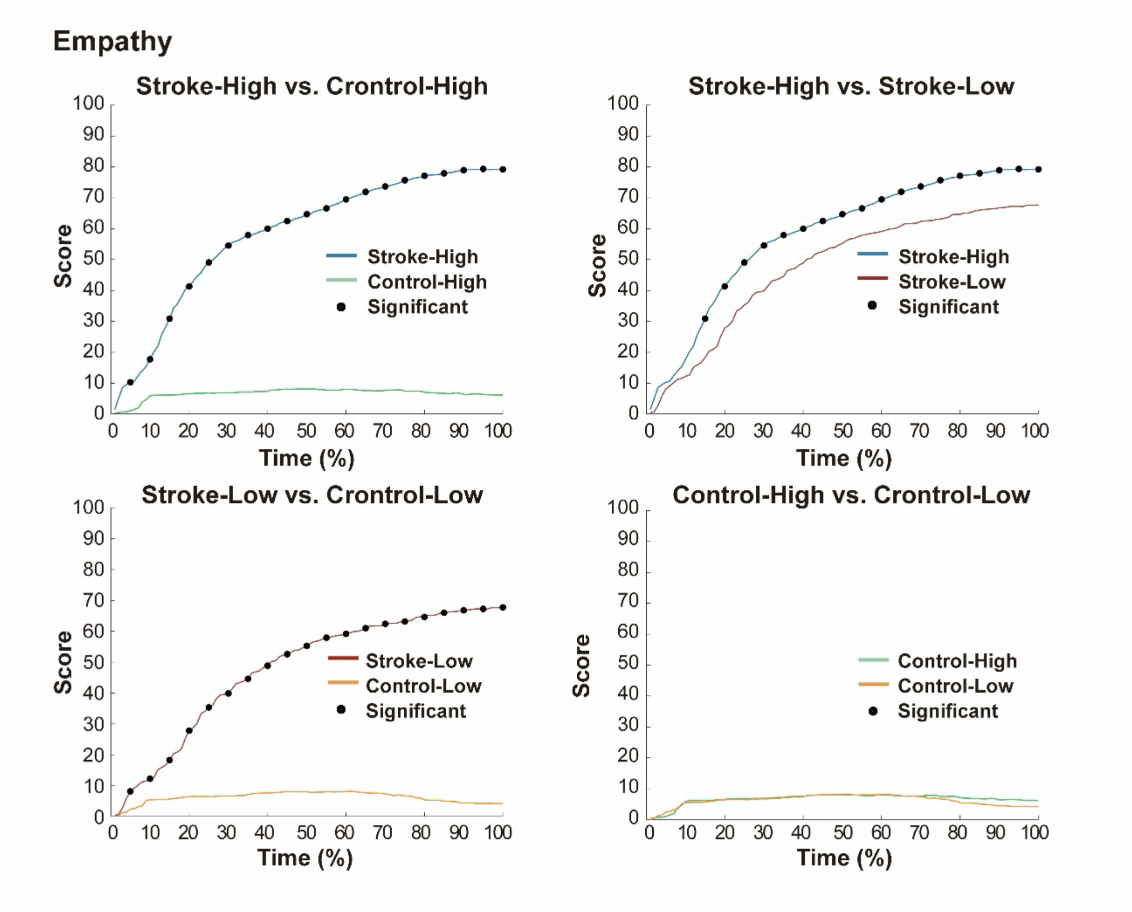


Figure S2. Timewise differences for empathy ratings. Time series are shown for four condition pairs (Stroke-High vs. Control-High, Stroke-High vs. Stroke-Low, Stroke-Low vs. Control-Low, and Control-High vs. Control-Low). Point-wise t-tests were conducted at every time point (1-100%). For visualization purposes, significant time points are indicated by black-filled circles plotted at every 5th time point ($p < .05$, FDR-corrected).

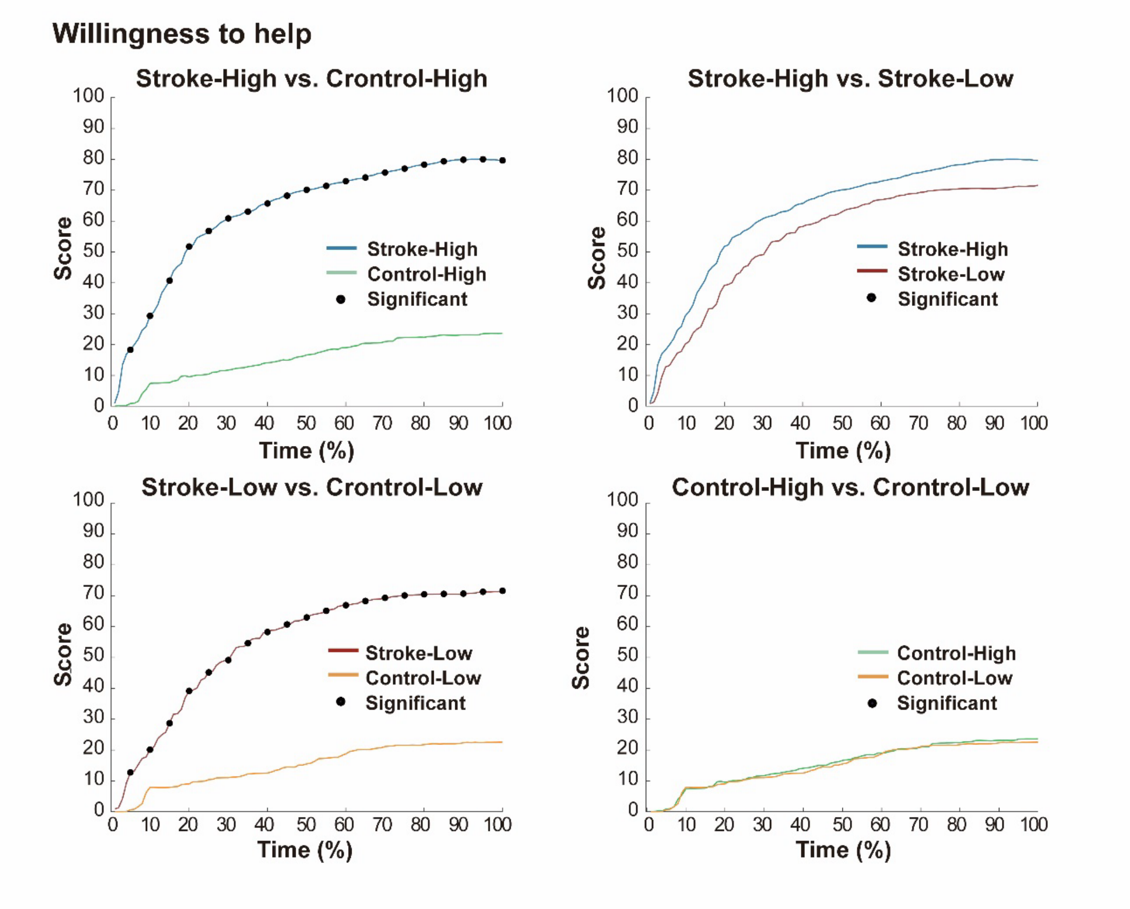


Figure S3. Timewise differences for willingness to help. Time series (1–100%) are shown for four condition pairs (Stroke-High vs. Control-High, Stroke-High vs. Stroke-Low, Stroke-Low vs. Control-Low, and Control-High vs. Control-Low). Point-wise t-tests were conducted at every time point (1-100%). For visualization purposes, significant time points are marked at every 5th time point ($p < .05$, FDR-corrected).

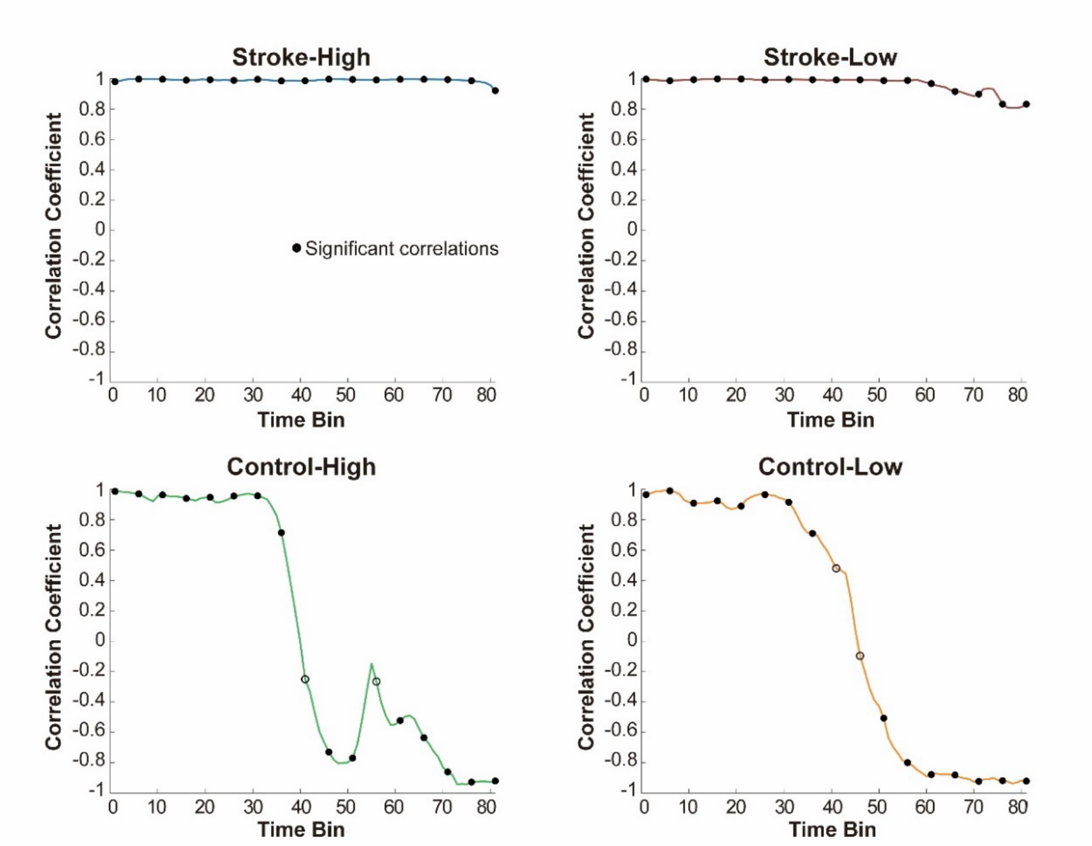


Figure S4. Sliding window Pearson's correlation analysis of ratings between empathy and willingness to help within each condition (window size = 20, step = 1). Correlations were computed across 81 time windows. Significant windows are marked, shown at every 5th time window for visualization purposes ($p < .05$, FDR-corrected).

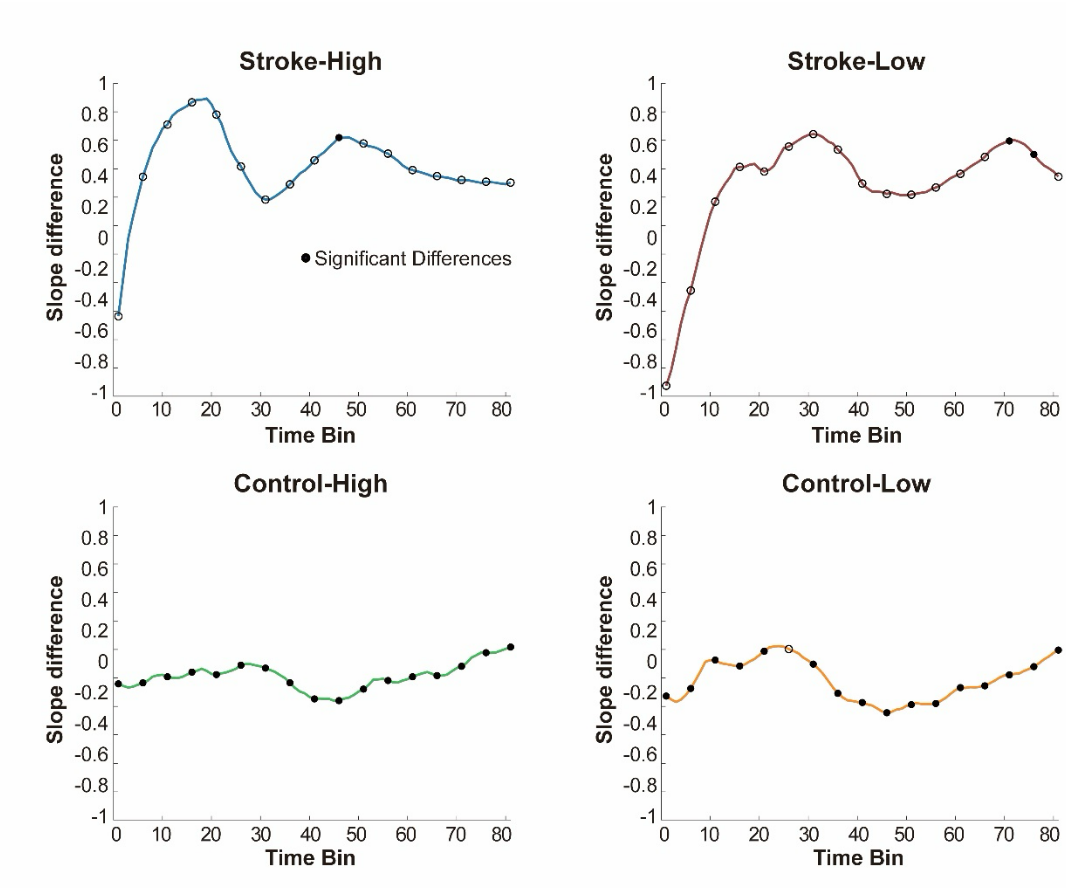


Figure S5. Sliding window slope comparisons analysis between empathy and willingness to help for each condition (window size = 20, step size = 1). Comparisons were conducted across 81 time windows. Positive values indicate steeper increases in empathy ratings relative to willingness to help ratings. Significant windows are marked at every 5th time window for visualization purposes ($p < .05$, FDR-corrected).

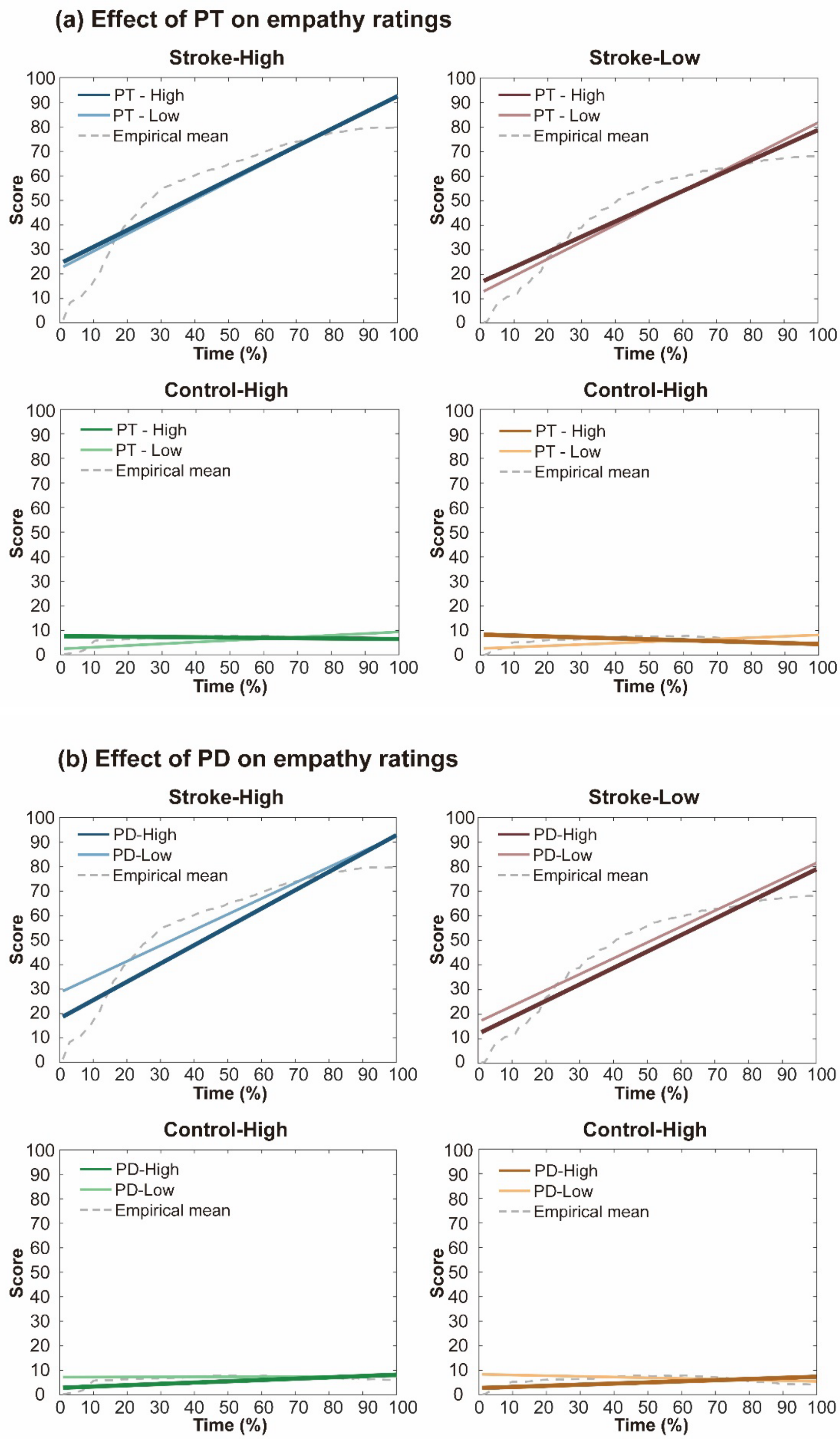
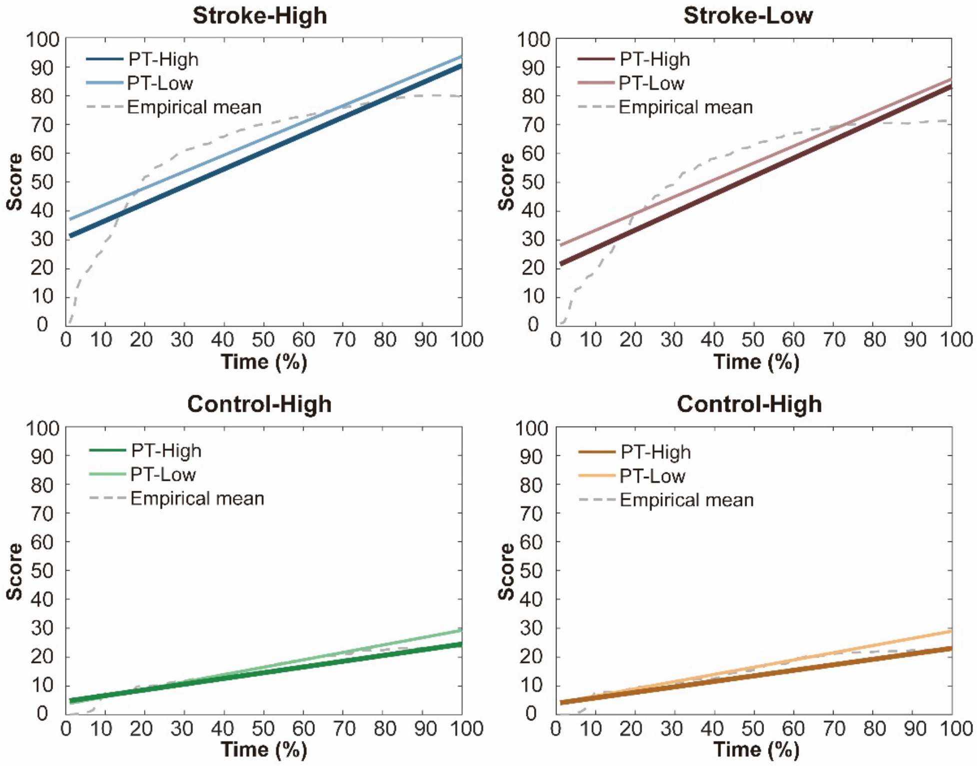

(a) Effect of PT on empathy ratings
Stroke-High
Stroke-Low
Control-High
Control-High
PT - High
PT - Low
Empirical mean
Score
Time (%)
(b) Effect of PD on empathy ratings
Stroke-High
Stroke-Low
Control-High
Control-High
PD-High
PD-Low
Empirical mean
Score
Time (%)

Figure S6. Predicted time-series ratings of empathy as a function of empathic traits. Model-implied ratings over normalized time (0 –100%) for each condition (Stroke-High, Stroke-Low, Control-High, Control-Low) at high and low levels of (a) perspective taking (PT) and (b) personal distress (PD) defined as one standard deviation below and above the sample mean (-1 SD and +1SD). Dashed lines indicate empirical mean ratings.

(a) Effect of PT on wllingness to help ratings



(b) Effect of PD on willingness to help

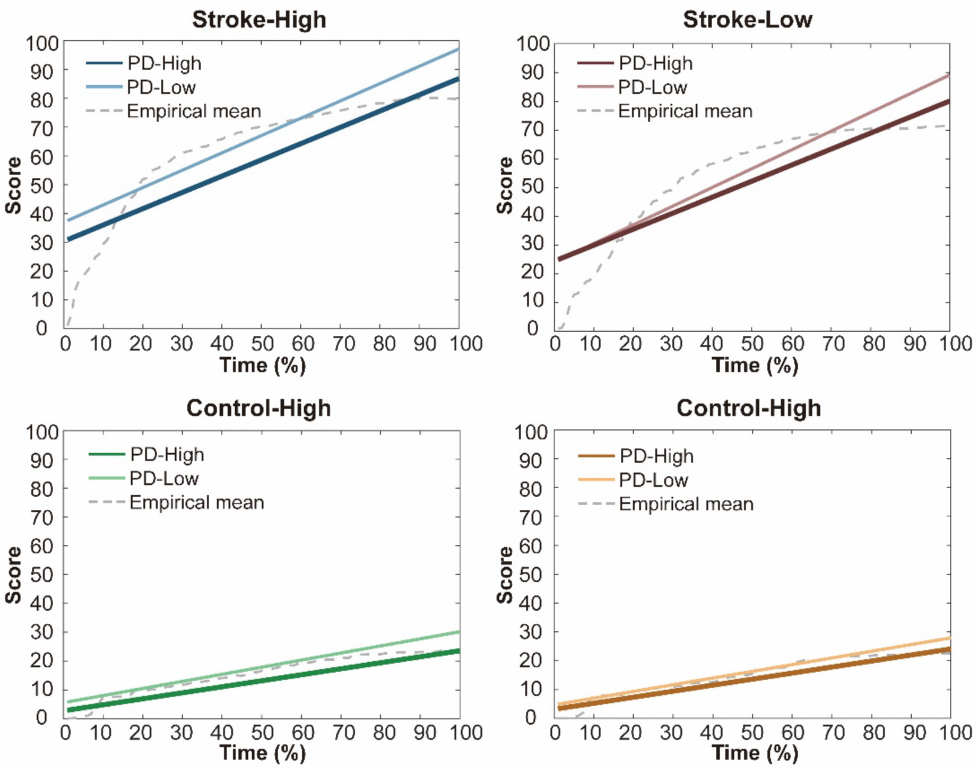


Figure S7. Predicted time-series ratings of empathy as a function of willingness to help traits. Model-implied ratings over normalized time (0 –100%) for each condition (Stroke-High, Stroke-Low, Control-High, Control-Low) at high and low levels of (a) perspective taking (PT) and (b) personal distress (PD) defined as one standard deviation below and above the sample mean (-1 SD and +1SD). Dashed lines indicate empirical mean ratings.

Table S1: Comparison between felt emotion and perceived emotion

Item	Condition (felt emotion vs. perceived emotion)	Median ± IQR felt	Median ± IQR perceived	U	p	r
ANGER	Stroke-Hight	2.06 ± 0.11	1.79 ± 0.35	77	< .001	1.79
	Stroke-Low	2.07 ± 0.14	1.56 ± 0.22	77	< .001	1.79
	Control-High	1.54 ± 0.15	1.11 ± 0.10	77	< .001	1.79
	Control-Low	1.55 ± 0.13	1.06 ± 0.05	77	< .001	1.79
EMPATHY	Stroke-Hight	3.43 ± 0.36	5.20 ± 0.87	28	< .001	0.12
	Stroke-Low	3.26 ± 0.42	4.82 ± 0.64	28	< .001	0.12
	Control-High	2.41 ± 0.17	1.69 ± 0.19	77	< .001	1.79
	Control-Low	2.45 ± 0.20	1.60 ± 0.07	77	< .001	1.79
FEAR	Stroke-Hight	3.77 ± 0.74	2.97 ± 0.38	74	< .001	1.69
	Stroke-Low	3.04 ± 0.55	2.39 ± 0.40	73	< .01	1.79
	Control-High	1.66 ± 0.27	1.18 ± 0.08	77	< .01	1.79
	Control-Low	1.67 ± 0.23	1.10 ± 0.07	77	< .01	1.79
HAPPINESS	Stroke-Hight	2.28 ± 0.43	1.36 ± 0.17	77	< .01	1.79
	Stroke-Low	2.25 ± 0.25	1.49 ± 0.16	77	< .01	1.79
	Control-High	3.32 ± 0.54	3.12 ± 0.50	61	= .32	1.25
	Control-Low	3.48 ± 1.11	3.25 ± 0.25	61	= .32	1.25

Item	Comparison (felt emotion vs. perceived emotion)	Median ± IQR felt	Median ± IQR perceived	U	p	r
NERVOUSNESS	Stroke-Hight	4.12 ± 0.47	3.54 ± 0.70	71	< .05	1.59
	Stroke-Low	3.43 ± 0.38	2.82 ± 0.44	72	< .05	1.62
	Control-High	2.08 ± 0.39	1.27 ± 0.15	77	< .01	1.79
	Control-Low	2.02 ± 0.36	1.29 ± 0.09	77	< .01	1.79
PITY	Stroke-Hight	3.50 ± 0.63	4.72 ± 0.85	28	< .001	0.12
	Stroke-Low	3.36 ± 0.49	4.25 ± 0.88	28	< .001	0.12
	Control-High	2.06 ± 0.29	1.21 ± 0.25	77	< .001	1.79
	Control-Low	1.95 ± 0.42	1.18 ± 0.15	77	< .001	1.79
SADNESS	Stroke-Hight	3.62 ± 0.40	4.11 ± 0.89	40	= .12	0.53
	Stroke-Low	3.60 ± 0.59	3.77 ± 0.81	49	= .71	0.84
	Control-High	2.16 ± 1.03	1.16 ± 0.39	77	< .01	1.79
	Control-Low	2.09 ± 1.03	1.18 ± 0.15	77	< .01	1.79

Table S2: a) Perceived emotion

Item	Comparison (Condition1 vs. Condition2)	Median ± IQR (Condition 1)	Median ± IQR (Condition 2)	W	P	r
ANGER	Stroke-Hight vs. Stroke-Low	1.79 ± 0.35	1.56 ± 0.22	28	< .05	0.89
	Stroke-High vs. Control-High	1.79 ± 0.35	1.11 ± 0.10	28	< .05	0.89
	Stroke-Low vs. Control-Low	1.56 ± 0.22	1.06 ± 0.05	28	< .05	0.89
	Control-High vs. Control-Low	1.11 ± 0.10	1.06 ± 0.05	19	= .45	0.32
EMPATHY	Stroke-Hight vs. Stroke-Low	5.20 ± 0.87	4.82 ± 0.64	28	< .05	0.89
	Stroke-High vs. Control-High	5.20 ± 0.87	1.69 ± 0.19	28	< .05	0.89
	Stroke-Low vs. Control-Low	4.82 ± 0.64	1.60 ± 0.07	28	< .05	0.89
	Control-High vs. Control-Low	1.69 ± 0.19	1.60 ± 0.07	22	= .23	0.51
FEAR	Stroke-Hight vs. Stroke-Low	2.97 ± 0.38	2.39 ± 0.40	28	< .05	0.89
	Stroke-High vs. Control-High	2.97 ± 0.38	1.18 ± 0.08	28	< .05	0.89
	Stroke-Low vs. Control-Low	2.39 ± 0.40	1.10 ± 0.07	28	< .05	0.89
	Control-High vs. Control-Low	1.18 ± 0.08	1.10 ± 0.07	24	= .13	0.64
HAPPINESS	Stroke-Hight vs. Stroke-Low	1.36 ± 0.17	1.49 ± 0.16	0	< .05	-0.9
	Stroke-High vs. Control-High	1.36 ± 0.17	3.12 ± 0.50	0	< .05	-0.9
	Stroke-Low vs. Control-Low	1.49 ± 0.16	3.25 ± 0.25	0	< .05	-0.9
	Control-High vs. Control-Low	3.12 ± 0.50	3.25 ± 0.25	6	= .22	-0.5

Item	Comparison (Condition1 vs. Condition2)	Median ± IQR (Condition 1)	Median ± IQR (Condition 2)	W	p	r
NERVOUSNESS	Stroke-Hight vs. Stroke-Low	3.54 ± 0.70	2.82 ± 0.44	28	< .05	0.89
	Stroke-High vs. Control-High	3.54 ± 0.70	1.27 ± 0.15	28	< .05	0.89
	Stroke-Low vs. Control-Low	2.82 ± 0.44	1.29 ± 0.09	28	< .05	0.89
	Control-High vs. Control-Low	1.27 ± 0.15	1.29 ± 0.09	7	= .30	-0.45
PITY	Stroke-Hight vs. Stroke-Low	4.72 ± 0.85	4.25 ± 0.88	28	< .05	0.89
	Stroke-High vs. Control-High	4.72 ± 0.85	1.21 ± 0.25	28	< .05	0.89
	Stroke-Low vs. Control-Low	4.25 ± 0.88	1.18 ± 0.15	28	< .05	0.89
	Control-High vs. Control-Low	1.21 ± 0.25	1.18 ± 0.15	18	= .58	0.26
SADNESS	Stroke-Hight vs. Stroke-Low	4.11 ± 0.89	3.77 ± 0.81	28	< .05	0.89
	Stroke-High vs. Control-High	4.11 ± 0.89	1.16 ± 0.39	28	< .05	0.89
	Stroke-Low vs. Control-Low	3.77 ± 0.81	1.18 ± 0.15	28	< .05	0.89
	Control-High vs. Control-Low	1.16 ± 0.39	1.18 ± 0.15	17.5	= .19	0.6

b) Felt emotion

Item	Comparison (Condition1 vs. Condition2)	Median ± IQR (Condition 1)	Median ± IQR (Condition 2)	W	P	r
ANGER	Stroke-Hight vs. Stroke-Low	2.06 ± 0.11	2.07 ± 0.14	20	= .38	0.38
	Stroke-High vs. Control-High	2.06 ± 0.11	1.54 ± 0.15	28	< .05	0.89
	Stroke-Low vs. Control-Low	2.07 ± 0.14	1.55 ± 0.13	28	< .05	0.89
	Control-High vs. Control-Low	1.54 ± 0.15	1.55 ± 0.13	5	= .31	-0.47
EMPATHY	Stroke-Hight vs. Stroke-Low	3.43 ± 0.36	3.26 ± 0.42	28	< .05	0.89
	Stroke-High vs. Control-High	3.43 ± 0.36	2.41 ± 0.17	28	< .05	0.89
	Stroke-Low vs. Control-Low	3.26 ± 0.42	2.45 ± 0.20	28	< .05	0.89
	Control-High vs. Control-Low	2.41 ± 0.17	2.45 ± 0.20	10	= 1	-0.04
FEAR	Stroke-Hight vs. Stroke-Low	3.77 ± 0.74	3.04 ± 0.55	28	< .05	0.89
	Stroke-High vs. Control-High	3.77 ± 0.74	1.66 ± 0.27	28	< .05	0.89
	Stroke-Low vs. Control-Low	3.04 ± 0.55	1.67 ± 0.23	28	< .05	0.89
	Control-High vs. Control-Low	1.66 ± 0.27	1.67 ± 0.23	17.5	= .61	0.22
HAPPINESS	Stroke-Hight vs. Stroke-Low	2.28 ± 0.43	2.25 ± 0.25	8	= .34	-0.4
	Stroke-High vs. Control-High	2.28 ± 0.43	3.32 ± 0.54	0	< .05	-0.9
	Stroke-Low vs. Control-Low	2.25 ± 0.25	3.48 ± 1.11	0	< .05	-0.9
	Control-High vs. Control-Low	3.32 ± 0.54	3.48 ± 1.11	3	= .08	-0.7

Item	Comparison (Condition1 vs. Condition2)	Median ± IQR (Condition 1)	Median ± IQR (Condition 2)	W	p	r
NERVOUSNESS	Stroke-Hight vs. Stroke-Low	4.12 ± 0.47	3.43 ± 0.38	28	< .05	0.89
	Stroke-High vs. Control-High	4.12 ± 0.47	2.08 ± 0.39	28	< .05	0.89
	Stroke-Low vs. Control-Low	3.43 ± 0.38	2.02 ± 0.36	28	< .05	0.89
	Control-High vs. Control-Low	2.08 ± 0.39	2.02 ± 0.36	15	= .94	0.06
PITY	Stroke-Hight vs. Stroke-Low	3.50 ± 0.63	3.36 ± 0.49	28	< .05	0.89
	Stroke-High vs. Control-High	3.50 ± 0.63	2.06 ± 0.29	28	< .05	0.89
	Stroke-Low vs. Control-Low	3.36 ± 0.49	1.95 ± 0.42	28	< .05	0.89
	Control-High vs. Control-Low	2.06 ± 0.29	1.95 ± 0.42	24.5	= .09	0.67
SADNESS	Stroke-Hight vs. Stroke-Low	3.62 ± 0.40	3.60 ± 0.59	26	= .05	0.77
	Stroke-High vs. Control-High	3.62 ± 0.40	2.16 ± 1.03	28	< .05	0.89
	Stroke-Low vs. Control-Low	3.60 ± 0.59	2.09 ± 1.03	28	< .05	0.89
	Control-High vs. Control-Low	2.16 ± 1.03	2.09 ± 1.03	25	= .08	0.7

Table S3. Baseline time slopes of empathy ratings and IRI-Related modulation of temporal change

	Baseline slope	β (Time ×IRI subscale)	SE	t-value	p-value
Based on PT					
Stroke-High	0.69	-0.002	0.001	-2.04	< .05
Stroke-Low	0.66	-0.007	0.001	-6.09	< .05
Control-High	0.03	-0.008	0.001	-6.74	< .05
Control-Low	0.01	-0.009	0.001	-7.82	< .05
Based on FS					
Stroke-High	0.69	0.002	0.001	1.42	= .16
Stroke-Low	0.66	-0.010	0.001	-8.81	< .05
Control-High	0.03	-0.001	0.001	-0.61	= .54
Control-Low	0.01	-0.002	0.001	-1.92	= .055
Based on EC					

Stroke-High	0.69	0.005	0.0013	4.05	< .05
Stroke-Low	0.66	-0.006	0.0013	-4.38	< .05
Control-High	0.03	-0.007	0.0013	-5.04	< .05
Control-Low	0.01	-0.007	0.0013	-5.13	< .05
Based on PD					
Stroke-High	0.69	0.011	0.0012	8.99	< .05
Stroke-Low	0.66	0.002	0.0012	1.89	< .05
Control-High	0.03	0.005	0.0012	4.14	< .05
Control-Low	0.01	0.007	0.0012	6.24	< .05

Note: Time slope = Baseline slope + β× IRI score

Table S4. Baseline time slopes of willingness to help ratings and IRI-related modulation of temporal change: Time slope = Baseline slope + β× IRI score

	Baseline slope	β (Time ×IRI subscale)	SE	t-value	p-value
Based on PT					
Stroke-High	0.58	0.004	0.002	1.59	= .011
Stroke-Low	0.60	0.005	0.002	2.44	< .05
Control-High	0.23	-0.008	0.002	-3.45	< .05
Control-Low	0.22	-0.008	0.002	-3.5	< .05
Based on FS					
Stroke-High	0.58	-0.002	0.002	-0.73	= .46
Stroke-Low	0.60	0.010	0.002	4.69	< .05
Control-High	0.23	0.001	0.002	0.36	= .72
Control-Low	0.22	-0.001	0.002	-0.39	= .69
Based on EC					
Stroke-High	0.58	-0.004	0.002	-2.23	< .05

Stroke-Low	0.60	0.003	0.002	1.64	= .10
Control-High	0.23	-0.003	0.002	-1.73	= .08
Control-Low	0.22	0.004	0.002	1.88	= .06
Based on PD					
Stroke-High	0.58	-0.005	0.002	-2.2	< .05
Stroke-Low	0.60	-0.01	0.002	-5.7	< .05
Control-High	0.23	-0.005	0.002	-2.3	< .05
Control-Low	0.22	-0.003	0.002	-1.4	= .17

Note: Time slope = Baseline slope + β× IRI score

References

Alawafi, R., Rosewilliam, S., & Soundy, A. (2023). Overcoming the monster! Perceptions of physiotherapy students regarding the use of stroke master plots for building therapeutic relationships; a vignette study. BMC Med Educ, 23(1), 311. doi: 10.1186/s12909-023-04301-5

Alzahrani, M. A., Dean, C. M., & Ada, L. (2009). Ability to negotiate stairs predicts free-living physical activity in community-dwelling people with stroke: an observational study. Aust J Physiother, 55(4), 277-281. doi: 10.1016/s0004-9514(09)70008-x

Batson, C. D., Early, S., & Salvarani, G. (1997). Perspective Taking: Imagining How Another Feels Versus Imaging How You Would Feel. Personality and Social Psychology Bulletin, 23(7), 751-758. doi: 10.1177/0146167297237008

Bellucci, G., Camilleri, J. A., Eickhoff, S. B., & Krueger, F. (2020). Neural signatures of prosocial behaviors. Neurosci Biobehav Rev, 118, 186-195. doi: 10.1016/j.neubiorev.2020.07.006

Bernhardt, B. C., & Singer, T. (2012). The neural basis of empathy. Annu Rev Neurosci, 35, 1-23. doi: 10.1146/annurev-neuro-062111-150536

Carlo, G. A., J; Buhman, DC. (1999). Facilitating and Disinhibiting Prosocial Behaviors: The Nonlinear
Interaction of Trait Perspective Taking and Trait Personal Distress
on Volunteering. BASIC AND APPLIED SOCIAL PSYCHOLOGY, 21(3), 189-197.

Chen, J., Putkinen, V., Seppala, K., Hirvonen, J., Ioumpa, K., Gazzola, V., . . . Nummenmaa, L. (2024). Endogenous opioid receptor system mediates costly altruism in the human brain. Commun Biol, 7(1), 1401. doi: 10.1038/s42003-024-07084-7

Christensen, E. R., Golden, S. L., & Gesell, S. B. (2019). Perceived Benefits of Peer Support Groups for Stroke Survivors and Caregivers in Rural North Carolina. N C Med J, 80(3), 143-148. doi: 10.18043/ncm.80.3.143

Davis, M. (1980). A Multidimensional Approach to Individual Differences in Empathy. Journal of Personality and Social Psychology, 10(85).

Decety, J., Bartal, I. B., Uzefovsky, F., & Knafo-Noam, A. (2016). Empathy as a driver of prosocial behaviour: highly conserved neurobehavioural mechanisms across species. Philos Trans R Soc Lond B Biol Sci, 371(1686), 20150077. doi: 10.1098/rstb.2015.0077

Decety, J., & Lamm, C. (2006). Human empathy through the lens of social neuroscience. ScientificWorldJournal, 6, 1146-1163. doi: 10.1100/tsw.2006.221

Eisenberg, N., & Miller, P. A. (1987). The relation of empathy to prosocial and related behaviors. Psychol Bull, 101(1), 91-119.

Eisenberg, N. F., R; Murphy, B; Karbon, M; Maszk, P; Smith, M; O'Boyle, C; Suh, K. (1994). The Relations of Emotionality and Regulation to Dispositional and

Situational Empathy-Related Responding. Journal of Personality and Social Psychology, 66(4), 776-797.

FeldmanHall, O., Dalgleish, T., Evans, D., & Mobbs, D. (2015). Empathic concern drives costly altruism. Neuroimage, 105, 347-356. doi: 10.1016/j.neuroimage.2014.10.043

Ferrari, P. F., & Coudé, G. (2018). Mirror Neurons, Embodied Emotions, and Empathy Neuronal Correlates of Empathy (pp. 67-77).

Fugl-Meyer, A. R., Jaasko, L., Leyman, I., Olsson, S., & Steglind, S. (1975). The post-stroke hemiplegic patient. 1. a method for evaluation of physical performance. Scand J Rehabil Med, 7(1), 13-31.

Gladstone, D. J., Danells, C. J., & Black, S. E. (2002). The fugl-meyer assessment of motor recovery after stroke: a critical review of its measurement properties. Neurorehabil Neural Repair, 16(3), 232-240. doi: 10.1177/154596802401105171

Hicks, E. C., Traci, M. A., & Korb, K. (2022). "Sympathy" vs."Empathy": Comparing experiences of I2Audits and disability simulations. Front Rehabil Sci, 3, 876099. doi: 10.3389/fresc.2022.876099

Iezzoni, L. I., & Long-Bellil, L. M. (2012). Training physicians about caring for persons with disabilities: "Nothing about us without us!". Disabil Health J, 5(3), 136-139. doi: 10.1016/j.dhjo.2012.03.003

Jackson, P. L., Meltzoff, A. N., & Decety, J. (2005). How do we perceive the pain of others? A window into the neural processes involved in empathy. Neuroimage, 24(3), 771-779. doi: 10.1016/j.neuroimage.2004.09.006

Karjalainen, T., Karlsson, H. K., Lahnakoski, J. M., Glerean, E., Nuutila, P., Jaaskelainen, I. P., . . . Nummenmaa, L. (2017). Dissociable Roles of Cerebral mu-Opioid and Type 2 Dopamine Receptors in Vicarious Pain: A Combined PET-fMRI Study. Cereb Cortex, 27(8), 4257-4266. doi: 10.1093/cercor/bhx129

Kruithof, W. J., van Mierlo, M. L., Visser-Meily, J. M., van Heugten, C. M., & Post, M. W. (2013). Associations between social support and stroke survivors' health-related quality of life--a systematic review. Patient Educ Couns, 93(2), 169-176. doi: 10.1016/j.pec.2013.06.003

Lamm, C., Batson, C. D., & Decety, J. (2007). The neural substrate of human empathy: effects of perspective-taking and cognitive appraisal. J Cogn Neurosci, 19(1), 42-58. doi: 10.1162/jocn.2007.19.1.42

Lamm, C., & Majdandzic, J. (2015). The role of shared neural activations, mirror neurons, and morality in empathy--a critical comment. Neurosci Res, 90, 15-24. doi: 10.1016/j.neures.2014.10.008

Lamm, C., Nusbaum, H. C., Meltzoff, A. N., & Decety, J. (2007). What are you feeling? Using functional magnetic resonance imaging to assess the modulation of sensory and affective responses during empathy for pain. PLoS One, 2(12), e1292. doi: 10.1371/journal.pone.0001292

Langhorne, P., Bernhardt, J., & Kwakkel, G. (2011). Stroke rehabilitation. Lancet, 377(9778), 1693-1702. doi: 10.1016/S0140-6736(11)60325-5

Lin, B. L., Mei, Y. X., Wang, W. N., Wang, S. S., Li, Y. S., Xu, M. Y., . . . Tong, Y. (2021). Unmet care needs of community-dwelling stroke survivors: a systematic review of quantitative studies. BMJ Open, 11(4), e045560. doi: 10.1136/bmjopen-2020-045560

Linacre, J. M., Heinemann, A. W., Wright, B. D., Granger, C. V., & Hamilton, B. B. (1994). The structure and stability of the Functional Independence Measure. Arch Phys Med Rehabil, 75(2), 127-132.

Mayo, N. E., Wood-Dauphinee, S., Ahmed, S., Gordon, C., Higgins, J., McEwen, S., & Salbach, N. (1999). Disablement following stroke. Disabil Rehabil, 21(5-6), 258-268. doi: doi: 10.1080/096382899297684.

McCauley, T. G., McAuliffe, W. H. B., & McCullough, M. E. (2024). Does empathy promote helping by activating altruistic motivation or concern about social evaluation? A direct replication of Fultz et al. (1986). Emotion, 24(8), 1868-1884. doi: 10.1037/emo0001339

McKevitt, C., Fudge, N., Redfern, J., Sheldenkar, A., Crichton, S., Rudd, A. R., . . . Wolfe, C. D. (2011). Self-reported long-term needs after stroke. Stroke, 42(5), 1398-1403. doi: 10.1161/STROKEAHA.110.598839

Mullin, D. J., Littenberg, B., & Rose, G. L. (2026). The association between patient's experience of empathy and self-reported health status in a large multisite primary care trial. Patient Educ Couns, 142, 109414. doi: 10.1016/j.pec.2025.109414

Nummenmaa, L., Glerean, E., Hari, R., & Hietanen, J. K. (2014). Bodily maps of emotions. Proc Natl Acad Sci U S A, 111(2), 646-651. doi: 10.1073/pnas.1321664111

Osborn, J., & Derbyshire, S. W. G. (2010). Pain sensation evoked by observing injury in others. Pain, 148(2), 268-274. doi: 10.1016/j.pain.2009.11.007

Preston, S., D., de Waal, B,M. (2002). Empathy: Its ultimate and proximate bases.

Ridgway, H. M., Bisson, E. J., & Brouwer, B. (2015). A Review of the Physical Demands of Stair Negotiation in
Healthy Aging and Following Stroke. Phys Med Rehabil Int, 2(7), 1057.

Sato, N., Tan, L., Tate, K., & Okada, M. (2015). Rats demonstrate helping behavior toward a soaked conspecific. Anim Cogn, 18(5), 1039-1047. doi: 10.1007/s10071-015-0872-2

Shamay-Tsoory, S. G. (2011). The neural bases for empathy. Neuroscientist, 17(1), 18-24. doi: 10.1177/1073858410379268

Truitt, D. O. K. A., Arumaithurai, M. D. K., & Young, D. O. N. (2023). Patient Satisfaction and Perception of Physician Empathy in Outpatient Community General Neurology Telemedicine. Telehealth and Medicine Today, 8(4). doi: 10.30953/thmt.v8.422

Voisin, J. I., Marcoux, L. A., Canizales, D. L., Mercier, C., & Jackson, P. L. (2011). I am touched by your pain: limb-specific modulation of the cortical response to a tactile stimulation during pain observation. J Pain, 12(11), 1182-1189. doi: 10.1016/j.jpain.2011.06.005

Watanabe, R., Kim, Y., & Kikuchi, Y. (2020). First-person perspective sharpens the understanding of distressful physical feelings associated with physical disability: A functional magnetic resonance study. Biol Psychol, 157, 107972. doi: 10.1016/j.biopsycho.2020.107972

Watanabe, R., Kim, Y., Kuruma, H., & Takahashi, H. (2022). Imitation encourages empathic capacity toward other individuals with physical disabilities. Neuroimage, 264, 119710. doi: 10.1016/j.neuroimage.2022.119710

Watanabe, R., & Kuruma, H. (2025). Understanding Empathy Toward Dissimilar Others in Challenging Everyday Interactions. Hum Brain Mapp, 46(11), e70283. doi: 10.1002/hbm.70283

Yang, N., Xiao, H., Cao, Y., Li, S., Yan, H., & Wang, Y. (2018). Does narrative medicine education improve nursing students' empathic abilities and academic achievement? A randomised controlled trial. J Int Med Res, 46(8), 3306-3317. doi: 10.1177/0300060518781476

Zaki, J., Weber, J., Bolger, N., & Ochsner, K. (2009). The neural bases of empathic accuracy. Proc Natl Acad Sci U S A, 106(27), 11382-11387. doi: 10.1073/pnas.0902666106

Zawawi, N. S. M., Aziz, N. A., Fisher, R., Ahmad, K., & Walker, M. F. (2020). The Unmet Needs of Stroke Survivors and Stroke Caregivers: A Systematic Narrative Review. J Stroke Cerebrovasc Dis, 29(8), 104875. doi: 10.1016/j.jstrokecerebrovasdis.2020.104875