

A Commonsense Theory of Mind-Body Interaction

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Abstract

We propose a logical formalization of a commonsense theory of mind-body interaction as a step toward a deep lexical semantics for words and phrases related to this topic.

Introduction

The English language is rich with words and phrases with meaning that is grounded in our commonsense theories of the interaction between the mind and the body. Concerning the mind's control of the body, we speak of motion that is *dexterous*, *graceful*, and *nimble*, or alternatively, *awkward* and *clumsy*. When the body moves without volition, we speak of *spasms*, *reflexes*, and *stumbles*. Concerning the perception of the world through the body to the mind, we speak of *sensations* and *hallucinations*. More subtly, we speak of the control that we have over our perceptions, as when we *tune out* distractions and *pay attention* to something. Conversely, we speak of the perception that we have of our own actions, when doing something *feels unnatural* or *uncomfortable*, or when we *get the hang of* doing something. When the normal functioning of the mind, the body, control, or perception is interrupted, we speak of being *paralyzed*, *dazed*, *numb*, *asleep*, *knocked out*, *deaf*, and *tired*, among a wide range of other mind-body states.

As a step toward a deep lexical semantics of these words and phrases, we propose a logical formalization of a commonsense theory of the interaction between the mind and the body. Our aim is to provide a theory that is as compact as possible, but rich enough to capture subtle differences in the meaning of these and other words and phrases. Our approach is to adopt a strong view of mind-body dualism, and formally describe the mental processes of control and perception as part of a larger theory of commonsense psychology.

Among the perils of formalizing a logical theory of mind-body interaction is the risk of trivializing the scholarship of generations of philosophers who have devoted their life's work to this topic, specifically within the field of philosophy of mind. Chalmers (2002) reviews the rich history of philosophical debate on this topic, and outlines the various positions that different philosophers have taken. The classic *dualism* offered in Descartes' *Meditations on First Philosophy* (1641) views a person as having both a physical body and a non-physical mind. Descartes' views are further characterized as *interactionalism*, in that the mind and body interact in both directions. Huxley (1874) offers an alternative view of dualism, *epiphenomenalism*, where this interaction is only in the direction from the body to the mind. Ryle (1949) begins a philosophical shift away from dualism toward *behavioralism*, the view that the mind is not to be seen as something distinct from the body and steering it from inside, but as an aspect of the body's own activities. The influence of neuroscience can be seen in the *Identity Theory*, put forth by Place (1956) and refined by Smart (1959), which holds that mental states are identical to their associated brain states: they are one in the same. Putnam (1973) argued against this view, noting that it is plausible that mental states are realizable by multiple brain states, and instead advanced the view of *functionalism*. Here mental states are seen as more abstract than their biological or mechanical realization, a view that has significant influence in contemporary artificial intelligence and cognitive science theories.

Our aim, however, is not to encode a theory that reflects contemporary scientific or philosophical views of the nature of mind-body interaction. Instead, our focus is the commonsense theory that non-scientists use to make everyday inferences, particularly with respect to the interpretation of natural language about the mind and the body. In focusing on commonsense (or naïve) psychology rather than scientific theory, this work is closer in spirit to Heider's common-sense psychology (1958) and Smedslund's psycho-logic (1997). The end result is a theory that most resembles Descartes' dualism and

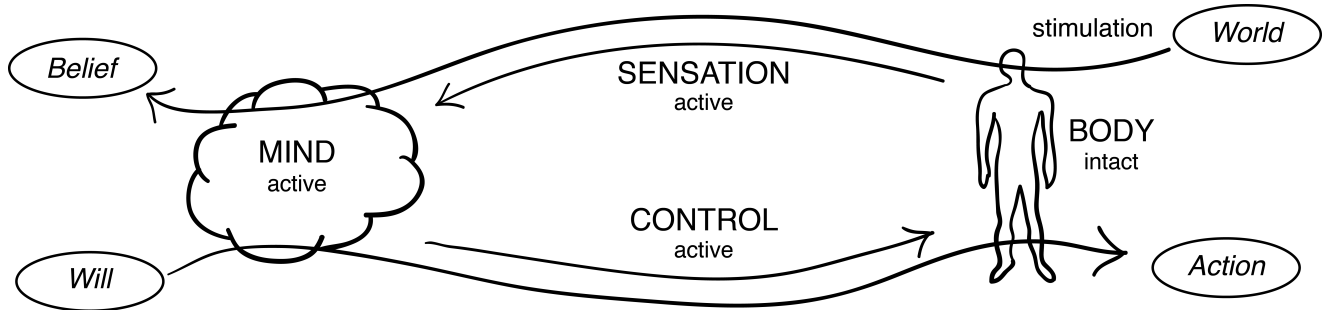


Figure 1. Mind-Body Interaction

interactionism, where a physical body and a non-physical mind interact in both directions.

Overview

The theory of mind-body interaction presented in this paper postulates that a person has both a mind and a body, which are connected by the two channels of sensation and control. The mind, the body, the sensation channel, and the control channel each have a 3-valued state, namely they are either active, impaired, disabled, or in the case of the body, intact, damaged, or destroyed. The control channel translates the will to do an action with the performance of the action in the world. The normal sensation channel operates to translate the stimulation provided by the world to beliefs in the mind. Figure 1 provides a diagram of the normal operation of these two channels.

The theory aims to provide an account of action and perception that is dependent on the status of the mind, the body, control, and sensation. Under this account, the mind's perception of the world is a consequence of the world stimulating the body, and is mitigated by the channel of sensation. With an intact body, an active mind, and active sensation, this perception yields beliefs; i.e. seeing is believing. Likewise, the body's actions are a consequence of the mind's will, mitigated by the channel of control. With an active mind, an intact body, and active control, will yields action.

This theory is presented here in first-order predicate logic, using the notation of the Common Logic Interchange Format (ISO/IEC 24707).

Mind and Body

We begin by specifying that a person has both a mind and a body, and that both have a three-valued state that characterizes their operating potential. We restrict our discussion to the type *person*, rather than the more general *agent*, so as not to include the wider range of non-human entities that are typically discussed in formalizations of agent-based theories, including organizations and machines. Coupled with a theory of physical objects and their interaction, we would further specify that the body is

a physical object, and the mind is not. However, here we simply note that bodies have some of the same properties that one might ascribe to other devices, namely that they are *intact*, *damaged*, or *destroyed*. Given a theory of scales, these properties could be characterized as high, medium, and low values on a scale of physical operability. Similarly, the mind is active, impaired, or inactive, which can be viewed as analogous values on a scale of non-physical operability.

A person has a body and a mind.

```
(forall (p)
  (if (person p)
    (exists (b m)
      (and (body b p)
           (mind m p))))))
```

Bodies are intact, damaged, or destroyed.

```
(forall (b p)
  (if (body b p)
    (xor (intact b)
         (damaged b)
         (destroyed b))))))
```

Minds are active, impaired, or inactive.

```
(forall (m p)
  (if (mind m p)
    (xor (active m)
         (impaired m)
         (inactive m))))))
```

Perception and Sensation

The first channel of interaction between the body and the mind is that of sensation, where the world's stimulation of the body (e.g. through sense organs) enables perception. The predicate *stimulate* is meant to connote the event where the world activates the sensory capacity of a person, e.g. when light hits their eyes, sound vibrates their eardrums, or objects pass across their skin. Here we use the predicate *eventuality* as an abstraction over states and events of the world, as in Hobbs (1985), and to leave underspecified the sorts of states and events that can stimulate the body. A richer theory could distinguish

between eventualities that are perceptible to people, i.e. generate sounds loud enough to be heard or reflect enough light into the eyes. Here we simply note that perception requires a mind and sensation that are not inactive.

Sensation, subsequently, is the channel by which this sensory information is passed to the mind. Here we treat sensation as a relation between this channel, the body, and the mind. We specify that this channel has three possible states, using the predicates *active*, *impaired*, and *inactive* to differentiate high, medium, and low values on a scale of operability. *Perception* and *misperception* are differentiated based on the state of this sensation channel, and on the state of the mind. In either case, perceiving or misperceiving imply belief (seeing is believing), where the predicate *believe* indicates that the person believes the proposition describing the eventuality.

The world stimulates people's bodies, if they are not destroyed.

```
(forall (e b) (4)
  (if (stimulate e b)
    (and (eventuality e)
      (not (destroyed b))))))
```

Sensation is a channel between the body and the mind of a person.

```
(forall (p) (5)
  (if (and (person p)
    (body b p)
    (mind m p))
    (exists (s)
      (sensation s b m))))
```

Sensation from the body to the mind is active, impaired, or inactive.

```
(forall (s b m) (6)
  (if (sensation s b m)
    (xor (active s)
      (impaired s)
      (inactive s))))
```

Perception of an eventuality implies stimulation of the body, sensation that is not inactive, and a mind that is not inactive.

```
(forall (e p b m) (7)
  (if (and (perceive e p)
    (eventuality e)
    (body b p)
    (mind m p)
    (sensation s b m))
    (and (stimulate e b)
      (not (inactive s))
      (not (inactive m))))))
```

Misperception implies impaired sensation or an impaired mind.

```
(forall (e p b m) (8)
  (if (and (misperceive e p)
    (eventuality e)
    (body b p)
    (mind m p)
    (sensation s b m))
    (or (impaired s)
      (impaired m))))
```

Perception and misperception imply believing.

```
(forall (e p) (9)
  (if (or (perceive e p)
    (misperceive e p))
    (believe e p)))
```

Action and Control

The second channel of interaction between the body and the mind is that of control, where a person's will to act leads to bodily action, mitigated by their level of control. The predicate *bodyAction* is used here to connote the sorts of things that bodies can do, and inasmuch as those bodies are bodies of people, then they are actions of people as well. Here *action* is used in its standard meaning (e.g. Davis & Morgenstern, 2005). However, some care must be made in the further interpretation of *bodyAction*. Here, bodily actions are meant to indicate some muscular exertion, as when someone clenches their fist to squeeze a sponge. However, this action may not result in motion of the hand, e.g. if instead one tries to squeeze a rock. In this theory, the bodily action (squeezing the rock) occurs in accordance with a person's will even if the intended result of the action (crushing a rock) fails to occur.

Like sensation, the channel of control can be in three states: *active*, *impaired*, and *inactive*. Bodily actions are initiated when a person wills them to occur. We use the predicate *will* as a relation between a person and an action that holds when the mind executes intended action. Accordingly, it is *will* that distinguishes an *intended* body action from an *unintended* body action. A special type of unintended bodily action is elaborated, a *reflex*, where stimulation of the body is viewed as the cause. We use the *dcause* predicate to indicate that the eventuality of the stimulation is the direct cause of the bodily action, as in Hobbs & Gordon (2005).

Body actions are actions of people.

```
(forall (a b p) (10)
  (if (and (bodyAction a b)
    (body b p))
    (action a p)))
```

Body actions may be intended or unintended.

```
(forall (a b) (11)
  (if (bodyAction a b)
    (xor (intended a)
      (unintended a))))
```

Body actions imply bodies that are not destroyed.

```
(forall (a b) (12)
  (if (bodyAction a b)
    (not (destroyed b))))
```

Control is a channel between the mind and the body of a person.

```
(forall (p) (13)
  (if (and (person p)
    (body b p)
    (mind m p))
    (exists (c)
      (control c m b))))
```

The mind's control of the body is active, impaired, or inactive.

```
(forall (c m b) (14)
  (if (control c m b)
    (xor (active c)
      (impaired c)
      (inactive c))))
```

Intended actions imply will and active control.

```
(forall (a b c m p) (15)
  (if (and (bodyAction a b)
    (intended a)
    (control c m b)
    (body b p))
    (and (will a p)
      (active c))))
```

Unintended actions imply no will.

```
(forall (a b p) (16)
  (if (and (bodyAction a b)
    (unintended a)
    (body b p))
    (not (will a p))))
```

Reflexes are unintended body actions caused by something that stimulates the body.

```
(forall (a b) (17)
  (if (reflex a b)
    (and (bodyAction a b)
      (unintended a)
      (exists (e)
        (and (stimulate e b)
          (dcause e a))))))
```

Control of Perception

Not completely independent, sometimes the control channel can influence the sensation channel. A person can listen intently to a distant conversation or track a moving object with their eyes. Likewise, a person can try to ignore a pain, avert their eyes, or shut out an annoying sound. We model all control of this sort as "tuning" in or out an eventuality of the world, enabling or preventing it from stimulating the body. To correctly notate the causal

predicates of *enable* and *prevent* within a first-order framework, it is necessary to reify the eventuality of the stimulation, the tuning in, and the tuning out. Here we adopt the style of ontological promiscuity proposed by Hobbs (1985), creating new primed predicates (*stimulate'*, *tuneIn'*, *tuneOut'*) where the unprimed versions are true exactly in the case that the eventuality (the first argument of each predicate) really exists. *Enable* and *prevent* take their standard meanings within a theory of causality, e.g. as causally involved in the causal-complex that produces the effect (Hobbs, 2005).

The action of "tuning in" to something is a body action that enables stimulation.

```
(forall (e p b e1 e2) (18)
  (if (and (tuneIn' e1 e p)
    (stimulate' e2 e b)
    (body b p))
    (and (bodyAction e1 b)
      (enable e1 e2))))
```

The action of "tuning out" something is a body action that prevents stimulation.

```
(forall (e p b e1 e2) (19)
  (if (and (tuneOut' e1 e p)
    (stimulate' e2 e b)
    (body b p))
    (and (bodyAction e1 b)
      (prevent e1 e2))))
```

Sensation of Action

Kinesthetic sense enables awareness of the position and movement of parts of the body by means of proprioceptors in the muscles and joints. Our theory allows us to simply model this sense in terms of bodily actions that are themselves the eventualities that stimulate the body. The predicate *stimulating* is used here to indicate body actions that have this property. The resulting perception of action that follows can be characterized in several ways, e.g. as dexterous, awkward, uncomfortable, fluent, etc. Sometimes, people just feel that a bodily action "feels weird." Here we present a simple formulation of *fluent* and *awkward* bodily actions, distinguished by the state of the control and sensation channels.

Some body actions stimulate the body, while other do not.

```
(forall (a b) (20)
  (if (bodyAction a b)
    (xor (stimulating a)
      (nonstimulating a))))
```

Body actions seem fluent to people when they are stimulating and where both sensation and control are active.

```
(forall (a p b m) (21)
  (if (and (fluent a p)
    (body b p)
    (mind m p)
    (control c m b)
    (sensation s b m))
    (and (stimulating a)
      (active c)
      (active s))))
```

Likewise, actions seem awkward to people when those actions are stimulating body actions and either sensation or control are impaired.

```
(forall (a p b m) (22)
  (if (and (awkward a p)
    (body b p)
    (mind m p)
    (control c m b)
    (sensation s b m))
    (and (stimulating a)
      (or (impaired c)
        (impaired s))))))
```

Mind-Body States

The axioms in the previous sections postulate the separation of the mind and the body, and identify the channels of control and sensation between them. Each of these four components is given a three-valued state. The mind, control, and sensation can be active, impaired, or inactive, and the body can be intact, damaged, or destroyed. Different combinations of these possible values each yield different mind-body states, each with their own set of inferred consequences.

For example, we can define the mind-body state of *unconscious* as the state where the body is intact, but the mind, control, and sensation are inactive.

```
(forall (p m b) (23)
  (if (and (unconscious p)
    (mind m p)
    (body b p)
    (control c m b)
    (sensation s b m))
    (and (intact b)
      (inactive m)
      (inactive c)
      (inactive s))))
```

With analogous axioms, a wide variety of mind-body states can be easily interpreted as variations of these three values for these four components. Table 1 lists several of these mind-body states with their corresponding properties.

Table 1 also serves to highlight some of the weaknesses of the theory as presented in this paper. Here, the states of being numb, blind, and deaf have identical properties, each with good condition of body, mind, and control, but inactive sensation. The solution to this problem, which would serve as the basis for an improved theory, would be

to formulate that the body is composed of body parts, some of which are sense organs, and to assign senses of touch, taste, smell, hearing, and sight as appropriate. Such an extension would also improve inferences about damage to the body, e.g. how damage to sense organs might affect the sensory modalities.

State	Body	Mind	Control	Sensation
Fine	+	+	+	+
Sore	/	+	+	+
Wounded	/	+	+	+
Tired	+	/	/	+
Numb	+	+	+	-
Blind/deaf	+	+	+	-
Tingly	+	+	+	/
Paralyzed	+	+	-	-
Dazed	+	/	+	+
Schizophrenic	+	/	+	/
Drunk	+	/	/	/
Dreaming	+	/	-	/
Sleeping	+	-	-	/
Unconscious	+	-	-	-
Brain dead	/	-	-	-
Dead	-	-	-	-

Table 1. Mind-body states (+ active or intact, / impaired or damaged, - inactive or destroyed)

Discussion

In many respects, the theory of mind-body interaction presented in this paper is more complicated than previous formalizations of action or perception. For example, Davis' high-level theories of visual perception (1988) and hand-eye coordination (1989) are extremely compact, introducing only a handful of new predicates to articulate key axioms. In contrast, this paper offers nearly two-dozen axioms with *more than* two-dozen new predicates, none that are suitably defined. Also lacking any presentation of provable theorems, our theory fails to meet several of the criteria that have traditionally been used to assess formalizations of content theories.

Instead, our work is motivated by a need for a deeper lexical semantics for natural language (Hobbs, 2008), where the logical formalizations are themselves rich enough to characterize differences in meaning at varying degrees of subtlety. With this aim in mind, the theory presented in this paper is elegant inasmuch as it affords distinctions in meaning, e.g. between *dexterous* action and *reflexes*, or between *sleeping* and *unconscious*.

By this criterion, however, there remain many aspects of the theory that need improvement. First, our treatment of perception (through sensation) fails to distinguish between sensory modalities, or recognize that sensations have degrees of clarity. As a consequence, the theory cannot distinguish between *seeing clearly* and *faintly hearing*. The theory also lacks any treatment of the subjective types of sensations, e.g. the concept of *pain*.

Second, our treatment of bodily actions does not distinguish those that cause motion, nor does it explore how different body parts move separately in coordinated action. As a consequence, the theory cannot distinguish between *clumsy* and *graceful*, nor draw inferences about *hand-eye coordination* or lack thereof.

Third, our treatment of control of perception is only at a very high level (tuning in and out), and fails to distinguish between the ways in which the mind controls different sensory modalities. For example, the eye *tracks* moving objects, *focuses* on distant and close objects, *closes* before sleeping, but *blinks* while awake. The theory provides no insight into which types of sensations can be easily tuned out, e.g. that people might find it easy to tune out the gentle sound of rain while reading a book, but not loud conversations.

Fourth, our treatment of the perception of action would also benefit from elaboration of the subjective types of sensations created by body actions. This would enable richer interpretations of language related to ergonomics, e.g. distinguishing *painful* from *natural* body motions, or of *comfortable grips* on handles and handholds.

Fifth, as mentioned earlier, the theory fails to distinguish between certain mind-body states. The differences between *deaf*, *blind*, and *numb* require (at least) distinctions in sensory modalities. This would also improve the interpretation of states such as *sleeping*, and how you can be *woken up* by a loud noise, but not a horrific photograph.

Despite all of these weaknesses, the theory presented here moves us toward a deeper lexical semantics for the language of mind-body interaction, more so than any previous formalization effort. Our approach was to adopt a strong view of mind-body dualism, following the original two-way interactionism of Descartes' *Meditations*. Alternative formulations of the same content, but based on different philosophical perspectives, are certainly possible. As extensions and alternative theories are put forth, it will be necessary to consider the criteria by which content theories such as this are to be evaluated and compared. Ultimately, theories of this sort should be evaluated by both *breadth* and *depth*, i.e. by their capacity to encode the meaning of natural language words and phrases (*coverage*), and their ability to generate correct inferences based on these encodings (*competency*).

Acknowledgments

The project or effort described here has been sponsored by the U.S. Army Research, Development, and Engineering Command (RDECOM). Statements and opinions expressed do not necessarily reflect the position or the policy of the United States Government, and no official endorsement should be inferred.

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