Lecture 01 : Foundations : Two Systems

Corrado Sinigaglia & Stephen A. Butterfill
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1. The Core Idea

According to a (modest) dual process theory, there are two (or more) mindreading processes which are distinct in this sense: the conditions which influence whether they occur, and which outputs they generate, do not completely overlap.

1.1. What Is a Two-Systems Theory? The Core Idea

In general, a modest two-systems theory concerning some cognitive domain (e.g. numerical cognition or moral cognition) claims just this:

> Two (or more) processes which enable functioning in this domain are distinct: the conditions which influence whether they occur, and which outputs they generate, do not completely overlap.[1]
>
> One process is faster than another: it makes fewer demands on scarce cognitive resources such as attention, inhibitory control and working memory.

A key feature of this two systems theory is its *theoretical modesty*: it involves no a priori commitments concerning the particular characteristics of the processes. Identifying characteristics of the process is a matter of discovery.

Further, their characteristics may vary across domains. The characteristics that distinguish processes involved in mindreading may not entirely overlap with those that distinguish processes involved in physical cognition, or in numerical cognition, or in moral cognition.

1.2. Minimal Illustration: Toxicity

What do you compute that enables you to track toxicity?

Option 2 (slow but accurate): measure molecular composition (feed it to shellfish and use liquid chromatography-mass spectrometry).

Option 1 (limited but fast): experience disgust …

> 'Disgust is thought to have originated in distaste, a food-rejection impulse or motivation triggered by the ingestion of unpleasant-tasting substances, prototypically those that are bitter (Chapman, Kim, Susskind, & Anderson, 2009; Rozin & Fallon,

[1] Compare Frankish & Evans (2009, p. 1): 'These theories come in different forms, but all agree in positing two distinct processing mechanisms for a given task, which employ different procedures and may yield different, and sometimes conflicting, results.'

1987). Because many bitter substances are toxic (Garcia, Hankins, Denton, & Coghlan, 1975), the role of distaste in food rejection has a clear and concrete adaptive function. Distaste appears to have very ancient origins: Even sea anemones, which first evolved some 500 million years ago, will expel bitter foods from their gastric cavity (Garcia et al., 1975)' (Chapman & Anderson 2013, p. 300).

1.3. In Which Domains Are There Two-Systems Theories?

Two-systems theories of one kind or another have been proposed for various domains. Here is a partial list of domains (note that some domains may overlap):

- reasoning and inference (Evans 2003)[2]
- judgement and decision-making (Kahneman 2002)
- memory (Jacoby 1991)
- social cognition (Gawronski et al. 2014)
- mindreading (Apperly & Butterfill 2009)
- number (Feigenson et al. 2004)
- ethics (Greene et al. 2004; Greene 2014)
- instrumental behaviour (Dickinson & Pérez 2018)
- learning (Dayan & Berridge 2014)

There are also domains where it is arguably coherent to suppose that researchers have identified what might be called a two-systems theory although this terminology is not in common use:

- social norms (Bicchieri 2016)
- physical cognition (Kozhevnikov & Hegarty 2001)
- categorical colour (Gilbert et al. 2006)[3]
- vision (Goodale & Milner 1992)
- agency (Sidarus et al. 2017)

2 We have linked the sources to references chosen to be accessible and useful; these are not the first or canonical sources for two-systems theories.

3 Note that the balance of evidence may not currently support the Gilbert et al. (2006)'s findings (see Witzel & Gegenfurtner 2011).

- syntax (Jackendoff 2003)

1.4. Systems 1 and 2 ???

Two systems theories often make claims beyond the core idea:

> 'Typically, one of the processes is characterized as fast, effortless, automatic, nonconscious, inflexible, heavily contextualized, and undemanding of working memory, and the other as slow, effortful, controlled, conscious, flexible, decontextualized, and demanding of working memory' (Frankish & Evans 2009, p. 1).

As several researchers have pointed out, this way of characterising systems goes beyond the evidence available and depends on assumptions about the characteristics coming in neat bundles (Adolphs 2010; Keren & Schul 2009).

There may also be reasons to doubt that bold hypotheses about these characteristics do much, if any, explanatory work (Butterfill 2007, 2020).[4]

1.5. Dual-Process or Two-Systems?

Although two systems theories are sometimes understood as making claims over and above those of a dual-process theory (e.g. Gawronski et al. 2014), others do not make any distinction:

> 'We use the term "system" only as a label for collections of cognitive processes that can be distinguished by their speed, their controllability, and the contents on which they operate' (Kahneman & Frederick 2005, p. 267).

We shall follow Kahneman in treating 'Two-Systems' and 'Dual-Process' as synonyms unless we encounter a need to distinguish them.

[4] The bold hypotheses do, however, make dual-process theories readily falsifiable. As Gawronski et al. (2014, p. 11) note, 'the number of events prohibited by dual-process theories—and thus their falsifiability—increases with the number of proposed covariations between dualities.' As we will see in considering mindreading and physical cognition, there are other ways to ensure that a dual-process theory is readily falsifiable.

2. Speed-Accuracy Trade-Offs (in Physical Cognition)

2.1. Physical Cognition: Impetus and Representational Momentum

Non-experts reliably judge that a projectile exiting a spiral tube will subsequently follow a spiral trajectory (McCloskey et al. 1980). Why?

Sometimes when adult humans observe a moving object that disappears, they will misremember the location of its disappearance in way that reflects its momentum; this effect is called *representational momentum* (Freyd & Finke 1984; Hubbard 2010).

The trajectories implied by representational momentum reveal that the effect reflects impetus mechanics rather than Newtonian principles (Freyd & Jones 1994; Kozhevnikov & Hegarty 2001; Hubbard et al. 2001; Hubbard 2013). And these trajectories are independent of subjects' scientific knowledge (Freyd & Jones 1994; Kozhevnikov & Hegarty 2001). Representational momentum therefore reflects judgement-independent expectations about objects' movements which track momentum in accordance with a principle of impetus.[5]

We might therefore conjecture that fast processes explain the spiral trajectory judgements observed by (McCloskey et al. 1980).

2.2. How Do Fast Process Influence Explicit Verbal Judgements?

In the case of physics, this appears to involve fast processes influencing the overall phenonemenal character of experiences, reflection on which which in turn influences judgements.

Phenomenology connects fast and slow processes indirectly. That is, there are content-respecting relations between fast and slow processes which may not require inferrential connections.

[5] Note that momentum is only one of several factors which may influence mistakes about the location at which a moving object disappears. See Hubbard (2005, p. 842): 'The empirical evidence is clear that (1) displacement does not always correspond to predictions based on physical principles and (2) variables unrelated to physical principles (e.g., the presence of landmarks, target identity, or expectations regarding a change in target direction) can influence displacement. [...] information based on a naive understanding of physical principles or on subjective consequences of physical principles appears to be just one of many types of information that could potentially contribute to the displacement of any given target'

Phenomenology connects fast and slow processes leaving room for discretion. That is, individuals are free to make judgments which conflict with model implicit in the fast processes, as expert physicists do (Kozhevnikov & Hegarty 2001).

2.3. Speed-Accuracy Trade-Offs

Any broadly inferential process must make a trade-off between speed and accuracy (see Heitz (2014) for a review). To illustrate, suppose you were required to judge which of two only very slightly different lines was longer. All other things being equal, making a faster judgement would involve being less accurate, and being more accurate would require making a slower judgement.[6]

But how can you trade accuracy for speed?

Kozhevnikov & Hegarty suggest that speed can be gained by relying on a simpler model of the physical:

> To extrapolate objects' motion on the basis of [e.g. Newtonian] physical principles, one should have assessed and evaluated the presence and magnitude of such imperceptible forces as friction and air resistance [...] This would require a time-consuming analysis that is not always possible. In order to have a survival advantage, the process of extrapolation should be fast and effortless, without much conscious deliberation. Impetus theory allows us to extrapolate objects' motion quickly and without large demands on attentional resources.' (Kozhevnikov & Hegarty 2001, p. 450)

This is one reason why it would be (or is) valuable to have distinct, independent systems. By using different models of a domain (e.g. impetus mechanics vs Newtonian mechanics in the physical domain), different systems can enable radically different, and complementary, trade-offs between speed and accuracy.

2.4. Historical Context for the Vertical Motion Example

Moletti (2000, p. 147), who was Galileo's predecessor in mathematics at Padua, reports an early (1576 or earlier) experiment on the motion of objects launched vertically in a dialogue:

[6] This idea is due to Henmon (1911), who has been influential although he didn't actually get to manipulate speed experimentally because of 'a change of work' (p.~195).

> ‘PR. […] Aristotle gave rise to doubts by saying that through one and the same medium the speed of things that are moved in natural movement, being of the same nature and shape, is as their powers. That is, if we were to let fall from the top of a tall tower two balls, one of twenty pounds of lead and the other of one pound, also of lead, that the movement of the larger would be twenty times faster than that of the smaller.
>
> ‘AN. This seems sufficiently reasonable to me; in fact, if I were asked I would grant it as a principle.
>
> ‘PR. You would be mistaken; in fact, both arrive at one and the same time, even if the test were done not once but many times. But what is more, a ball of wood, either larger or smaller than one of lead, let fall from the same height at the same time as the lead ball, would descend and touch the earth or ground at the same moment in time.’

Glossary

automatic On this course, a process is *automatic* just if whether or not it occurs is to a significant extent independent of your current task, motivations and intentions. To say that *mindreading is automatic* is to say that it involves only automatic processes. The term ‘automatic’ has been used in a variety of ways by other authors: see Moors (2014, p. 22) for a one-page overview, Moors & De Houwer (2006) for a detailed theoretical review, or Bargh (1992) for a classic and very readable introduction 7

cognitively efficient A process is *cognitively efficient* to the degree that it does not consume working memory and other scarce cognitive resources. 7

fast A *fast* process is one that is to to some interesting degree cognitively efficient (and therefore likely also some interesting degree automatic). These processes are also sometimes characterised as able to yield rapid responses.

Since automaticity and cognitive efficiency are matters of degree, it is only strictly correct to identify some processes as faster than others.

The fast-slow distinction has been variously characterised in ways that do not entirely overlap (even individual author have offered differing characterisations at different times; e.g. Kahneman 2013; Morewedge

& Kahneman 2010; Kahneman & Klein 2009; Kahneman 2002): as its advocates stress, it is a rough-and-ready tool rather than an element in a rigorous theory. 2

representational momentum Sometimes when adult humans observe a moving object that disappears, they will misremember the location of its disappearance in way that reflects its momentum (Freyd & Finke 1984; Hubbard 2010). There are several competing models of representational momentum and related phenomena involving misremembered location (Hubbard 2010). 5

track For a process to *track* an attribute is for the presence or absence of the attribute to make a difference to how the process unfolds, where this is not an accident. (And for a system or device to track an attribute is for some process in that system or device to track it.)

Tracking an attribute is contrasted with *computing* it. Unlike tracking, computing typically requires that the attribute be represented. 2

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