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Francken, J.C.; Slors, M.

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Neuroscience and everyday life: Facing the translation problem

Jolien C. Francken^{a,*}, Marc Slors^b

^a Department of Psychology, University of Amsterdam, P.O. Box 15915, 1001 NK Amsterdam, Netherlands

^b Faculty of Philosophy, Theology and Religious Studies, Radboud University Nijmegen, P.O. Box 9103, 6500 HD Nijmegen, Netherlands

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ABSTRACT

To enable the impact of neuroscientific insights on our daily lives, careful translation of research findings is required. However, neuroscientific terminology and common-sense concepts are often hard to square. For example, when neuroscientists study lying to allow the use of brain scans for lie-detection purposes, the concept of lying in the scientific case differs considerably from the concept in court. Furthermore, lying and other cognitive concepts are used unsystematically and have an indirect and divergent mapping onto brain activity. Therefore, scientific findings cannot inform our practical concerns in a straightforward way. How then can neuroscience ultimately help determine if a defendant is legally responsible, or help someone understand their addiction better? Since the above-mentioned problems provide serious obstacles to move from science to common-sense, we call this the 'translation problem'. Here, we describe three promising approaches for neuroscience to face this translation problem. First, neuroscience could propose new 'folk-neuroscience' concepts, beyond the traditional folk-psychological array, which might inform and alter our phenomenology. Second, neuroscience can modify our current array of common-sense concepts by refining and validating scientific concepts. Third, neuroscience can change our views on the application criteria of concepts such as responsibility and consciousness. We believe that these strategies to deal with the translation problem should guide the practice of neuroscientific research to be able to contribute to our day-to-day life more effectively.

1. Introduction

Can brain scans read thoughts? If so, can they detect lies? Questions such as these are frequently being asked today, and jurors seriously consider the use of neuroimaging data in court (Costandi, 2013; McCabe, Castel, & Rhodes, 2011; Roskies, Schweitzer, & Saks, 2013). This example illustrates, on the one hand, the quick rise of the field of neuroscience. On the other hand, however, it highlights the demand for translation of scientific findings about the brain into language that is appropriate to improve practices outside of cognitive neuroscience. Usually this is the language of common-sense cognitive concepts ('CCCs', such as 'lying'). The use of CCCs to report research findings suggests that these terms have the same meaning in scientific and non-scientific contexts, but this is often not the case (Figdor, 2013; Francken & Slors, 2014). In the lie-detection case, for instance, one might argue that neuroscientists are not really studying lying: fMRI studies investigate trivial lies with no consequences, which may not count as lies in an everyday context (Pardo & Patterson, 2013). The neuroscience of 'love' provides another example. In these studies, what is usually studied is a passive, emotional experience in response to seeing a picture of a beloved (Van Stee, 2017). Although this leaves out many aspects of the

meaning of love in our day-to-day life, this nuance is lost as soon as scientific results are translated to popular statements such as 'neuroscience now proves that love is addictive'.

Hence, quite apart from methodological questions (concerning e.g., reliability and generalizability) it is vital to study the use of common-sense cognitive concepts when reporting research findings. For there often exists a conceptual gap between neuroscientific findings and the concepts we are ultimately interested in. Only when we bridge this gap neuroscience will really be able to contribute to determine if someone lied during interrogation, or to help someone understand his addiction better.

If the CCCs of our everyday 'folk-psychology' could be operationalised unproblematically and unambiguously in neuroscientific experiments, the outcomes of these experiments would ideally directly inform CCC-based practices. Given the conceptual gap, however, we should be cautious in interpreting the outcomes of neuroscience experiments simply as, say, results about 'lying', 'free will', 'love', or any other folk-psychological category. How then can neuroscientific findings be translated in terms that speak to our practical concerns in a non-misleading, non-naïve way? Let us call this the 'translation problem'.

After elaborating on the translation problem in Section 2, we will

* Corresponding author.

E-mail addresses: j.c.francken@uva.nl (J.C. Francken), m.slors@tr.ru.nl (M. Slors).

discuss three different solutions to it (Sections 3–5). These are not mutually exclusive, but highlight different ways in which neuroscience can impact on our CCC-based practices. The first solution to the translation problem is to allow neuroscience to go beyond the traditional folk-psychological array of CCCs and introduce what may be viewed as new CCCs. As is noted by an increasing number of researchers and journalists, it has become common to express feelings, thoughts and attitudes in terms of one's dopamine, serotonin or adrenaline levels. In Section 3 we will discuss the relation between this emerging 'folk-neuroscience' and folk-psychology. The next two solutions hinge on the idea that neuroscience can improve our current array of CCCs. In Section 4 we will discuss how neuroscience might influence the taxonomy of CCCs by refining and validating scientific concepts. In Section 5 we will discuss an illustrative case study - responsibility - that shows how neuroscience can alter the criteria of applicability of certain CCCs. Finally, in Section 6, we will discuss the question how neuroscience research practices can be amended to improve its contribution to our everyday life.

2. The translation problem

The 'translation problem' is the problem of drawing conclusions about CCCs from brain data. In a previous paper, we discussed the fact that CCCs need to be refined and operationalised into tasks before they can be connected to activity in the brain (Francken & Slors, 2014). This process, we argued, involves multiple, interpretive steps. As a consequence, brain data cannot inform us unambiguously about the nature of CCCs (see also Anderson, 2010; Burnston, 2016; Poldrack, 2006; Rathkopf, 2013). This is where the translation problem emerges: it is not possible to simply apply neuroscientific findings¹ to our CCC-based practices. In order to see why translating scientific data to CCC-based practices is a serious problem, let us briefly rehearse the different steps from CCCs to brain data and their associated problems (for an extensive discussion, please refer to Francken & Slors, 2014; see also Poldrack et al., 2011). The main obstacle for a direct translation from neuroscientific findings to CCCs lies in the fact that there are (at least) three steps to get from CCCs to the brain, where each of these steps contains a many-to-many rather than a one-to-one mapping (Fig. 1).

2.1. Common-sense cognitive concepts (CCCs) and scientific cognitive concepts (SCCs)

The first step takes us from our folk-psychological, common-sense concepts to scientific cognitive concepts (SCCs) (Fig. 1: (a)). CCCs are usually too coarse-grained and unspecific to be objects of informative and well-controlled scientific research. Therefore, they are typically turned into more formal and fine-grained SCCs. Often, SCCs and CCCs have the same name (e.g. 'memory') but the SCCs usually differ from CCCs in being partitioned into sub-concepts (e.g., 'working memory', 'long-term memory'). Ideally, SCCs are formalized versions of CCCs with more precise definitions that are shared by the scientific community. However, this is often not the case. Many SCCs capture only

Fig. 1. The translation problem. Because of the many-to-many mapping between common-sense cognitive concepts (CCCs), scientific cognitive concepts (SCCs), operationalisations in experimental tasks and brain data, it is not possible to simply apply neuroscientific findings to our everyday practices.

part of the meaning of CCCs (Francken & Slors, 2014). Sometimes the meaning of SCCs and associated CCCs are even conflicting (Figdor, 2013). For instance, Figdor showed that a neural system initially associated with 'reward' defined in a behaviourist way, i.e., a stimulus associated with increased frequency of response, is later related to feelings of pleasure that are associated with the ordinary meaning of the term 'reward'.

Divergence does not only occur when we go from CCCs to SCCs, but also in the reverse direction. For example, the CCC 'consciousness' plays a role in everyday explanations of experiences and actions. But the concept is also important in legal practices (is the defendant responsible?), medical practices (is the patient conscious?), and psychiatric practices (are this patient's beliefs misinformed or is she delusional?). Definitions of the CCC can diverge depending on the everyday context, resulting in a many-to-many mapping between CCCs and SCCs and reduced applicability of scientific findings to our common-sense concepts (or ecological validity, see for a discussion e.g., Sullivan, 2009).

2.2. SCCs and task operationalisations

After the first step of converting a CCC to an SCC, a second step is required to be able to study the behavioural and neural mechanisms of an SCC (Fig. 1: (b)). In order to study SCCs in the brain, an experimental task has to be designed to activate the cognitive process associated with the SCC. For example, the Wisconsin card-sorting task is used to measure the underlying cognitive and neural mechanisms of 'task-switching'. In this task, subjects have to match a target card to one of four cards. Matching can be based on colour, shape or number of the items on the cards, and the correct matching rule has to be inferred by the subjects, based on feedback about whether their previous match was correct or incorrect. The matching rule changes every ten cards. Scoring well on the task requires the ability to adapt quickly to a new rule (Berg, 1948), i.e. the ability to switch tasks. However, some researchers use the same task to study the SCC 'working memory', since the participant has to remember which is the current matching rule (e.g., 'match on colour') (Keefe, 1995). This clearly complicates the interpretation of the scientific findings: how does the researcher know whether the measured brain activity correlates with task-switching or with working memory?

Two issues are important here. First, the example shows that there is no shared or systematic relationship between concepts and tasks. As a consequence, different tasks and versions of tasks are used in the scientific community to tap into a particular concept - and there is even more diversity when including different levels of investigation, i.e. animal studies, patient studies, etc. This situation impedes the generalizability (or external validity, see Sullivan, 2009) of research findings (Poldrack et al., 2011).

Second, the example demonstrates that SCCs are *interpretations* of certain behaviour elicited by specific tasks. Whether the Wisconsin card-sorting task measures working memory or task-switching is not something that can be determined by scientific experiments. SCCs are human constructs, derived from CCCs that preceded neuroscience by millennia (Danziger, 1997; Hacking, 1986). CCCs are designed to interpret, explain and predict behaviour in everyday life (Dennett, 1971,

¹ The translation problem as we will discuss it here pertains to the translation of neuroscientific results to domains outside of neuroscience. Similar problems exist with respect to the translatability of the results of cognitive psychology and artificial intelligence, since there the sub-steps that we will discuss in this section, from common-sense cognitive concepts (CCCs) to scientific cognitive concepts (SCCs) and from SCCs to tasks are necessary too. Yet, we think the problems for neuroscience are more visible and severe because, first, lay people take neuroscience more seriously than cognitive psychology findings, e.g. because neuroscience findings are accompanied by fancy brain images (see e.g., Roskies, 2008; Trout, 2008; Weisberg, Keil, Goodstein, Rawson, & Gray, 2009), increasing the impact. Second, in neuroscience experiments, the dependence on behaviour - that is equally big - is less clear. Usually operationalisations are not extensively discussed because the brain data are what makes the findings exciting. On the contrary, in cognitive psychology studies behavioural measures are the only outcome measures, requiring discussion of what was actually experimentally manipulated.

1987), not to provide scientific explanations (see Section 5). This observation contradicts a common, though usually implicit view in neuroscience (and outside of science) according to which SCCs are natural kinds. If this implicit view is correct, SCCs such as working memory and task switching refer to distinct, potentially tractable neural processes. If that would be the case, determining whether the activity found during the Wisconsin card-sorting task codes for working memory or for task-switching would simply require further neuroimaging, behavioural or even genetic evidence. Instead, we think that scientists should discuss which of these SCCs provides the best interpretation of the task and agree upon a shared standpoint.

The step from SCCs to experimental tasks is the main source of the translation problem. The many-to-many mapping between concepts and tasks hinders the conclusions – in terms of SCCs or even CCCs – that can be drawn from neuroscientific studies. In Section 4 we will discuss a promising approach aiming to improve the consistency of ‘cognitive ontologies’, which might reduce the problems encountered in this step. However, the more fundamental, interpretative nature of the step from SCC to task remains.

2.3. Task operationalisations and the brain

The third step from CCC to the brain is the one from a task, designed to target the SCC, to the brain (Fig. 1: (c)). There are currently many different techniques for brain measurement, producing a diversity of brain data informing us about presence or absence, localization, and timing of putative cognitive processes. In addition to the variety in types of data, there is the problem of selectivity. For instance, in neuroimaging research, a particular task usually activates multiple brain regions and a particular brain region is often involved in many different tasks (Poldrack, 2011). Thus, this step adds even more complexity to the translation from neuroscientific experiments back to our scientific and common-sense concepts.

2.4. From brain data back to CCCs

All three steps from CCCs to the brain contain many-to-many mappings. These mappings are complicated because cognitive concepts are human kinds, rather than natural kinds, whose operationalisation involves interpretive wiggle room. The choices that researchers make to bridge the gaps between CCCs, SCCs, tasks and the brain are often unsystematic and not explicitly discussed or substantiated (Figdor, 2013; Francken & Slors, 2014). The result is a translation problem: cognitive neuroscience cannot inform our CCC-based practices simply by investigating the nature of CCCs – such as ‘free will’, ‘love’, and ‘lying’ – and then handing us unambiguous verdicts about them. Neuroscientific experiments need to be ‘translated’ in order to impact on cognitive concepts that function in our common-sense practices.

Here one could object that some neuroscientists might not be interested to translate their findings to day-to-day life: they might simply want to understand how the brain functions. However, the lay public’s enthusiasm for neuroscience does stem mainly from the fact that it promises to reveal something about ourselves, e.g. how we make decisions, where our desires come from, why we have certain preferences or whether we correctly assess the reasons for which we act. Indeed, most cognitive neuroscientists do ultimately aim to impact on our day-to-day practices and this demands the translation of brain data to CCCs.

But if direct applicability is a too naive picture, what would be the more realistic one? What would count as successful translation? Differently put: how can cognitive neuroscience help us improve CCC-based practices? In the next sections, we distinguish three potential strategies for translating neuroscience to CCC-based practices: modifying folk-psychology, refining SCCs to improve CCCs, and changing the application criteria of CCCs. Our aim is to offer a starting point for discussion: the three strategies are not exhaustive and each of them should be developed and extended in future projects.

3. Modifying folk-psychology

A first strategy is to explore the potential of neuroscience to modify the ‘folk-psychology’ in which our CCCs function by introducing new CCCs. In this section, we will show that these new concepts can articulate the realisation that the brain is the source of our behaviour and that they can inform and alter our phenomenology. In order to introduce this strategy, it is instructive to start with what may appear as a direct influence of neuroscience on our CCC-based practices. The lay public is increasingly using ideas and terminology from the neurosciences to interpret and understand day-to-day life.

Recent studies have systematically analysed the use of neuroscientific ideas and concepts in lay communication. For instance, Vrecko demonstrated how brain-centred ideas about alcoholism provide new means to understand this addiction (Vrecko, 2006). First, he argues that there is a change from a focus on changing someone’s life-long habits to a focus on changing the state of one’s neurochemistry. Second, individuals recognize the brain as the ultimate cause of their addiction and incorporate expert neuroscience terminology into their own reports and explanations. In another study, Rodriguez analysed the use of the words ‘brain’ and ‘mind’ in everyday language (Rodriguez, 2006). He found that brain and mind are used in similar metaphors, e.g., ‘the mind/brain is a muscle’: an example of the former is a phrase such as ‘mental exercise’ and an illustration of the latter is the observation that a physics student referred to problem solving as applying ‘brain sweat’. In addition to a substitution for the word ‘mind’, the word ‘brain’ is used as explanation for mental phenomena, such as ‘knowing’: ‘...after about 40–45 s, the brain thinks, ‘Wow, what’s making that thing go for so long?’’.

Examples such as these can easily be multiplied. They seem to show that insights and terminology gained from cognitive neuroscience can be inserted *directly* into our CCC-based practices. The idea that this can indeed be done is in fact older than the contemporary emergence of ‘folk-neuroscience’ (FN). In 1979, the philosopher Paul Churchland proposed that the advance of neuroscience would gradually obviate the need for our folk-psychological vocabulary (Churchland, 1979, 1981). The rationale behind this prediction is the idea that folk-psychology and neuroscience have similar aims. Both aim at explaining and predicting human behaviour. Moreover, and importantly, they both aim to do so by postulating entities that are causally responsible for our behaviour but unobservable in normal circumstances. The entities proposed by neuroscience – specific ‘neuro-cognitive’ processes – are much more in line with our scientific outlook than the entities of folk-psychology – the mental states captured by our CCCs. This is why, according to Churchland, it is a conceivable scenario that folk-psychology (FP, our language of CCCs) will gradually be eliminated while the language of neuroscience will come to pervade our day-to-day talk about each other and ourselves.

Is the current emergence of folk-neuroscience an illustration of the onset of this scenario? While some of the rhetoric in the literature might suggest this, we believe this is misleading. We will argue that the emerging FN does not count as the onset of the elimination of FP. In order to explain why, we first need to distinguish two axes along which neuroscience and FP can be contrasted and then ask how FN can be located on both axes.

FP does not just consist of a set of terms – ‘belief’, ‘desire’, ‘thinking’, ‘feeling’, ‘being conscious of’, etc. – but just as well of specific ways in which these terms are put to use in explaining and rationalizing behaviour. FP explains actions, typically, not in a neuroscientific manner, i.e., by citing internal responses to carefully controlled stimuli in experimental paradigms. It is a contested matter what folk-psychological explanations do typically look like (see e.g., Andrews, 2012; Dennett, 1991; Hutto, 2008; Ratcliffe, 2007; Zawidski, 2013). They are said to cite not just internal-to-the-skull mental states as the causes of action, but they often also explain actions e.g., by invoking their contexts, by referring to norms or normative expectations, cultural patterns, or by

referring to first-personal, experiential aspects which allow us to empathize with the actor. FP explanations are not just concerned with the causes of actions, but just as much with their justification and the extent to which we can ‘understand’ them in the colloquial sense of that term.

Thus, we can contrast neuroscience and FP in terms of their *vocabularies* (SCCs vs. CCCs), but we can also contrast them in terms of *styles of explanation* (see also Hochstein, 2016). Does FN resemble FP or neuroscience when comparing, respectively, vocabularies and styles of explanation? In terms of the first contrast, FN is clearly on the side of science, introducing terms such as dopamine, mirror neurons, etc. With respect to the second contrast, we present three arguments to demonstrate that FN, at present, makes sense and finds its use only *within the context of FP* and that FN explanations contrast with scientific explanations in the same way as FP explanations do.

Let us start with two typical FN quotes. The first is taken from an online-forum for alcoholism treatment:

It appears that on occasions when I would take that first glass of wine, the surge in my endorphins was so swift and high that the effects of the wine would kick in and I would lose all control as I wanted to maintain that state... and of course ending up in a disaster. (Vrecko, 2006, p. 302)

The second example features mirror neurons, which are associated by many researchers with action understanding and empathy (see e.g., Goleman & Boyatzis, 2008; Pavlovich & Krahne, 2012). Here’s an example taken from management literature of a given CEO of Southwest Airlines whose behaviour is considered to be a great example of creating social coherence on the work floor:

We could practically see him activate the mirror neurons [...] in each person he encountered. He offered beaming smiles, shook hands with customers as he told them how much he appreciated their business, hugged employees as he thanked them for their good work. And he got back exactly what he gave. (Goleman & Boyatzis, 2008, p. 78)

The first thing to note about examples such as these is that FN terminology and FP terminology are mixed effortlessly. The first quote mixes the ‘surge in my endorphins’ with folk-psychological phrases such as ‘lose control’, and ‘wanted to maintain’. In the second quote, mirror neuron activity (FN) is mixed with FP notions such as thanking and appreciating.

Secondly, first-personal, experiential aspects of actions play an important role. This is particularly clear in the first quote, where an FN term is used to describe a feeling, while FP terminology is used to describe this person’s attitude towards this feeling and her subsequent actions. The FN terminology serves to convey the intensity of the person’s feeling as well as its inevitability: this is how my brain is wired. In the second quote this experiential aspect is less clearly present. However, when it comes to the CEO getting “back exactly what he gave”, this can most easily be glossed as positive feelings of appreciation and being appreciated.

Thirdly, and very importantly, both quotes make sense against a background of norms and normative expectations. FP explanations of actions do not just explain actions in terms of their causes, they also justify and excuse actions and make them ‘understandable’. Both quotes show the extent to which the FN terminology is put to use in this way. In the first quote, the FN terminology underscores the intensity of feelings and the inevitability of wanting more alcohol and thus partly excuses the further drinking (or at least it makes this understandable). In the second quote, a social norm is at play (being friendly to others) as well as an economic norm (this is how you get people to reciprocate).

These examples show that FN terminology serves an FP purpose, rather than a scientific purpose, in terms of styles of explanation. Thus, even if the FP vocabulary would be endangered by FN (but we should note that currently nothing indicates this), it would be misleading to say that FN is in the process of replacing FP.

FN *could* be an addition or an enrichment to FP, however. But then

we need to be sure that FN labels such as ‘my serotonin levels are rising quickly’ are not merely fancy translations for common CCCs such as ‘I am feeling mildly euphoric’. Indeed, we believe there is possibly a profound way in which insights from neuroscience can enhance our CCC-based practices. Take the example of insights into the mechanisms underlying addiction. Being able, as an addict, to interpret experiences such as, say, craving or a drug-induced rush, in terms of the relevant brain processes may shed a useful new light on them. It may connect the experience to other physiological phenomena, for instance, either co-occurring ones or similar ones that occur at other times. It may also inform the experience through known follow-up processes or known causes or incentives. In short, the known functionality of the brain processes underlying such experiences can inform these experiences and hence subtly transform them into more ‘lucid’ or informative self-experiences – even though the neural mechanisms underlying addiction are not yet fully understood. In fact, this kind of self-understanding, or ‘functional phenomenology’, is arguably at play in the quote by Vrecko above. Note that we are merely stressing the possibility of functional phenomenology as an improvement of our everyday self-understanding. This possibility relies on the correctness of the neuroscientific explanation it is based on. Sometimes, however, neuroscientific concepts are used in FN long before there is scientific consensus on their explanatory use. The mirror neurons in the Goleman & Boyatzis quote above are a case in point, as there is still scientific controversy over the idea that such neurons code for empathy (see e.g. Hickok, 2014; Gallagher, 2007).

The discovery of mirror neurons did open our eyes to the widespread phenomenon of neural resonance – people responding involuntarily to the behaviour of others by replicating (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992) or complementing (Newman-Norlund, van Schie, van Zuijlen, & Bekkering, 2007) this behaviour. The everyday phenomenology of observing social interactions is thus slightly altered, becoming more informative, through neuroscientific knowledge.

To conclude, FN does not replace or eliminate FP. Rather, FN has the potential to enrich our self-understanding with more than fashionable ‘neuro-translations’ of pre-existing CCC’s.

4. Refining SCCs as a step towards improved CCCs

A second strategy for dealing with the translation problem is to address the unsystematic use of SCCs in neuroscience itself. We started out by noting that the translation problem follows from the many-to-many mapping between CCCs, SCCs, tasks and the brain. The complexity of this situation is often not explicitly acknowledged by scientists resulting in a variety of tasks and concept labels that are sometimes inconsistent. Trying to remedy the unsystematic use of cognitive concepts in neuroscience (Poldrack et al., 2011) is, *ipso facto*, addressing the translation problem. If SCCs are unambiguously operationalised in terms of a specific set of tasks, neuroscience may be able to provide information about these SCCs. This would limit the translation problem to the task of interpreting findings about specific SCCs in everyday language, i.e. in terms of CCCs.

A taxonomy of SCCs is also known as a ‘cognitive ontology’ (Price & Friston, 2005). Currently the revision of existing cognitive ontologies is hotly debated (Janssen, Klein, & Slors, 2017) and elaborate proposals have been presented (e.g., Anderson, 2015; see McCaffrey & Machery, 2016 for critique; see also Poldrack & Yarkoni, 2015; Poldrack et al., 2011). Let us discuss one proposal for improvement and refinement of our taxonomy of SCCs by Lenartowicz and colleagues as an example (Lenartowicz, Kalar, Congdon, & Poldrack, 2010). Contrary to what is now the case in much of cognitive neuroscience, the SCCs that result from their method carve out a coherent set of behaviours systematically correlated with specific brain activity. Instead of asking which brain regions are associated with a particular cognitive process, which is usually the approach in neuroimaging

studies, Lenartowicz et al. aimed to find which brain areas are *selective* for a particular mental function.

They started with a set of concepts related to 'cognitive control', and retrieved all papers in the BrainMap database (Laird, Lancaster, & Fox, 2005) matching the search terms (Sabb et al., 2008). The neuroimaging data from all of these studies was combined, and by means of machine learning techniques the authors were able to examine whether the proposed cognitive processes could be mapped to independent brain areas. They used pairwise comparisons of all combinations, e.g., response inhibition vs. task selection, response selection vs. working memory, etc. to test whether a construct was associated with a unique pattern of brain activity. The classifier scores reflected discriminability of one construct from each of the other constructs. If the neural pattern elicited by a particular concept could not be distinguished from the pattern associated with other constructs, as was the case for 'task-switching', the authors reasoned that the construct deserves no separate place in the cognitive ontology because it might just be a different label for the same process as associated with, for example, the label 'response inhibition'. On the other hand, the concept of 'response selection' could be quite well distinguished from other cognitive control concepts. The authors therefore concluded that we should keep the concept of 'response selection' in our cognitive ontology, while there is no place for 'task-switching'.

We believe the work of Lenartowicz and colleagues is a good illustration of the project of building and improving a systematic scientific ontology of cognitive functions. However, we do not share their strong metaphysical claims about the ontological reality of cognitive functions (see also Figdor, 2011; McCaffrey, 2016). Our disagreement follows from the discussion in Section 2. There we argued that cognitive concepts do not refer directly to neural processes – they refer to behaviour elicited by certain tasks and indirectly to the neural activity that drives this behaviour.

So, what can we learn from the observation that the neural activity behind a range of tasks described in terms of 'response selection' turns out to be a homogeneous class? Under the assumption that this homogeneous class of neural activity signifies similarities in the functional processing underlying the behaviour elicited by these tasks, it demonstrates that the *set of tasks* that are thought to test 'response selection' is a 'neuro-cognitively' coherent one. Conversely, the fact that the neural processing underlying 'task-switching' is heterogeneous indicates that the set of tasks testing 'task-switching' taps into a diverse range of processes. In this way, cognitive neuroscience data can help grouping and systematizing a *task ontology*, an important first step to update a cognitive ontology. When we have built a consistent task ontology, informed by neuroscientific data,² we can turn to the next step. By inferring the commonalities in cognitive processing within sets of tasks, we might update the cognitive labels associated with these tasks. In this way, neuroscience can provide indirect arguments for either separating, combining or eliminating constructs in our cognitive ontology (Badre, 2011; Bilder et al., 2009; Figdor, 2011; Francken & Slors, 2014).

What can such revision of our cognitive ontology mean for our CCC-based practices, as well as e.g. law and medicine? Here it is important to recognize the fact that SCCs are loosely modelled on CCCs. Even though 'response selection' is a *scientific* cognitive concept, the meaning of such a concept is still directly derived from and connected to our everyday folk-psychology. The term 'selection' in 'response selection', for instance, is apt only if it bears sufficient resemblance to, say, selecting apples to buy from a pile in the supermarket, or to selecting a book to read from a shelf. This provides some opening for translating conclusions about SCCs back to CCCs. But we should be very careful

here and this procedure should be further explored and developed in a future project.

Even though it may seem unlikely from the current perspective that FP will be eliminated altogether, neuroscience has (or should have) altered our self-image in a number of respects already. Think, for instance, of the fact that we turn out to have (much) less conscious control over our actions than many would have thought (Wegner, 2002). In a similar way, changes in our cognitive ontologies might tweak the meaning of CCCs by altering parts of them in specific contexts. In all likelihood, we will retain much of the CCC vocabulary of our current FP to designate these new classes of cognitive processes. But it may be argued that in such a case the old vocabulary of CCCs takes on meanings that are so new that this may count as a form of weak eliminativism (see e.g., Murphy, 2017). For this issue to be decided, we believe that it is important to look at the style of explanation that the 'new' CCCs will be involved in. If these styles resemble the current styles and purposes of FP explanation, we would claim, based on the considerations in Section 3, that a neuroscience-based adjustment of our CCCs can best be viewed, not as weak elimination, but as a science-informed modification of FP.

5. Changing the application criteria of CCCs

A third strategy of addressing the translation problem is by exploring the possibility that neuroscience changes the criteria for application of existing CCCs. For instance, the neuroimaging work of Owen and colleagues demonstrated that some patients that fulfil the clinical criteria for a diagnosis of vegetative state retain the ability to understand language and to respond to spoken commands through their brain activity (Owen et al., 2006). Findings such as these could provide us with arguments to change our criteria for attributing consciousness. As a more elaborate case study, let us here discuss the concept of responsibility. While this cannot itself be considered a cognitive concept, it is an integral part of CCC-based practices, such as giving and asking for reasons, and legal practices. Responsibility is connected with and dependent on CCCs such as 'free will' and what philosophers refer to as 'reasons responsiveness' (Dennett, 1984; Fischer & Ravizza, 1998). Thus, if its application criteria shift under the influence of neuroscientific research this is a good example of the translation of neuroscientific results to CCC-based practices.

How can cognitive neuroscience inform our common-sense notion of 'responsibility' in a productive way? Crucially, neuroscience is not in a position to provide empirical evidence showing that responsibility does or does not exist. Responsibility is assessed in a social context: the answer to the question of whether we should hold someone responsible for his actions cannot be found by carving nature at its joints. Moreover, it is a complex concept, consisting of mental and behavioural conditions, that is applied in a flexible way, according to criteria that vary over time and cultures (Mackor, 2013). When understanding and categorizing behaviour as 'responsible' in the context of our common-sense practices, we use these implicit application criteria than we learn from examples (Churchland, 2006). Yet, even though responsibility is a normative concept, some authors argue that neuroscience has the potential to change our responsibility practices (Churchland, 2006; Mackor, 2013; Meynen, 2014).

First, the criteria for application of responsibility could change (Mackor, 2013). Neuroscientific insights might provide arguments to update our cognitive criteria of responsibility with neuroscientific criteria, complementing arguments from psychology and psychiatry (Roskies, 2006). Take the notion of free will, which is widely regarded as a precondition for responsibility. Patricia Churchland argues, plausibly, that insights into the neurobiology of one important criterion for free will, self-control, should lead us to update this notion (Churchland, 2006). Self-control comes in degrees: we have little control over behavioural changes as a result of hormonal influences, for instance in puberty, while we have more control over decisions such as whether to

² Importantly, a valid task ontology is corroborated by converging evidence from studies using multiple analyses methods applied to different types of data (single-cell recordings, electrophysiological data, behavioural data, fMRI, TMS, etc.) (see also Anderson, 2010).

buy an ice cream. The degree of self-control that we can assert in a certain situation is dependent on many different parameters. Churchland argues that neuroscience contributes to the understanding of relevant parameters, e.g. by providing insights into the neural basis of reward and punishment, fear, and decision-making (Churchland, 2002).

Second, neuroscience might help to determine whether particular (categories of) persons fit the criteria. For instance, neuroscientific findings suggesting that adolescents' brains are not fully mature might offer an argument to not try juveniles in adult court (Buchen, 2012; Feld, Casey, & Hurd, 2013; Sifferd, 2013).

Third, neuroscientific tests might provide complementary ways to assess responsibility or legal insanity (Aharoni, Funk, Sinnott-Armstrong, & Gazzaniga, 2008; Meynen, 2013). More specifically, if neuroscientific tests agree with psychiatric findings, self-reports and psychological assessments, this will reinforce the evidence. On the other hand, if the findings conflict, this might provide reasons to re-evaluate the other sources of evidence.

The case of responsibility extends our discussion in Section 4, where we argued that neuroscientific insights might affect CCC-based practices indirectly when we construct a consistent cognitive ontology build upon a scientifically validated task ontology. Rather than aiming to show that the CCC 'free will' does or does not exist, studies into the neural mechanisms underlying e.g., decision-making, self-control and reward-processing can provide scientifically informed arguments relevant to some of our application criteria for responsibility. Yet, we fully agree with Churchland that a concept of responsibility or free will "updated to fit what we know about the nervous system must also reflect our social need for a working concept of responsibility" (Churchland, 2006, p. 43; see also Dennett, 2003). Balancing this social need with advancing insights into e.g., which kinds of self-control are and which are not reasonable to ask of people may yield shifting criteria, application or assessment of the concept of responsibility too.

6. How could cognitive neuroscience contribute to our day-to-day practices?

In the sections above we have argued that neuroscientific contributions to our CCC-based practices should, all in all, not be expected to issue directly from the CCC or SCC terminology in which neuroscientists couch their findings. When neuroscientists speak of 'lying' or 'love', it is unlikely that their research captures the full-blown common-sense concepts of lying or love. This was the message of Section 2. Instead, we have outlined three different ways in which neuroscience is currently contributing to our day-to-day practices. Neuroscience can propose new folk-neuroscience CCCs that articulate the realisation that the brain is the source of our behaviour and that can inform and alter our phenomenology (Section 3), it can provide empirical arguments to update (parts of) CCCs by constructing a valid task ontology and consistent cognitive ontology (Section 4), and it can change our views on the application criteria of certain CCCs (Section 5). If cognitive neuroscientists would be more aware of these actual ways in which they can contribute to our CCC-based practices – rather than the idealised picture of a direct contribution that we discarded in Section 2 – they may perhaps be able to impact on our daily lives more effectively. In this section, we end by making some remarks on what such awareness may involve.

First, neuroscientists could become more sensitive to insights from phenomenology and recognize the potential of neuroscientific findings to elucidate our everyday self-experience (e.g., de Haan, Rietveld, Stokhof, & Denys, 2013). Currently a movement called 'front-loading phenomenology' advocates the use of phenomenological insights as driving forces behind neuroscientific research (Gallagher & Zahavi, 2007). A good case in point is the phenomenological distinction between our sense of agency and the sense of ownership of our movements. This distinction has yielded influential neuroscientific models (e.g., Chaminade & Decety, 2002; Farrer & Frith, 2002; Farrer et al.,

2003). But neuroscientists should also become aware of the fact that some findings point to experiential phenomena that cannot be captured easily in terms of pre-existing CCCs or SCCs. For instance, the discovery of mirror neurons has focused our attention to an overlap at the experiential level between noticing one's own intentions and emotions and recognizing them in others. Rather than using traditional terminology (such as 'simulation' or 'social perception') some neuroscientists recognize the possibility of employing new terminologies here. Vittorio Gallese speaks of the 'shared manifold', for instance (Gallese, 2003). This new terminology may be more apt and can be considered as an enrichment of our FP (Slors, 2009).

Second, to improve the unsystematic use of SCCs in neuroscience researchers could focus on the behavioural and neural correlates of tasks before turning to the SCCs (see also Bilder et al., 2009; Francken & Slors, 2014). The approach of Lenartowicz and colleagues that we discussed in Section 4 provides a clarifying example. Thus, instead of asking which brain areas are associated with e.g., 'romantic love', we suggest to start with the question whether different neural processes are involved in task A and task B. Definitions at the task level are often more concrete, stable and explicit while definitions at the cognitive concept level are often imprecise, inconsistent, and temporally instable (Bilder et al., 2009). Later, one could provide arguments based on these empirical findings to tag the behaviour and associated processes in task A and B with different cognitive labels. This strategy might result in more systematic and reliable links between CCCs/SCCs, experimental tasks and cognitive or neural processes. In addition, it enables the use of cognitive ontologies for data repositories that can in turn be used for automated meta-analyses and concept validation (Bilder et al., 2009). Moreover, to improve the contribution of neuroscientific findings to our CCC-based practices, researchers should be more aware of the potential different definitions of SCCs and CCCs and the need for explicit translation. When reporting findings in cognitive concept terminology, there is a risk that these terms might have a different or conflicting meaning in an ordinary context. For instance, the fact that cognitive constructs are operationalized in experiments and are therefore only indirectly associated with neural correlates, could be made more explicit to avoid misunderstanding and unwarranted expectations (Figdor, 2013).

Thirdly, to increase the impact of neuroscience on our daily practices, neuroscientists could set up more collaborations with people outside of their own field. Rather than aiming to overthrow e.g. juridical practices by transforming or eliminating concepts such as 'responsibility', they might aim to sharpen existing criteria of application of such concepts. A good example is The Research Network on Law and Neuroscience. From 2007 onwards, this initiative connects leading neuroscientists and legal scholars to explore ways of deploying neuroscientific insights to improve the fairness and effectiveness of the criminal justice system. Another beneficial initiative is the interdisciplinary collaboration of principal researchers from the field of learning and memory resulting in the book 'Science of Memory Concepts' (Roediger, Dudai, & Fitzpatrick, 2007). For each of several core memory concepts, three position papers described how the concept is viewed in the author's particular tradition. Subsequently, another researcher integrated these contributions and elucidated key points of agreement and disagreement, aiming for a more unified science of memory.

Changes such as these reflect the three strategies to tackle the translation problem outlined in this paper. They are examples of what awareness of the translation problem can and should lead to. It is important to stress that they are not meant to be exhaustive, just like further reflection and research might highlight further strategies for meeting the translation problem.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the

online version, at <http://dx.doi.org/10.1016/j.bandc.2017.09.004>.

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