Objectification of the content of consciousness

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Abstract

The content of consciousness has been strictly escaped from scientific research due to its subjective, non-objective property. Here we show an empirical way to objectify the content of consciousness. We reconsidered the subjective-objective distinction and argued that it was not necessarily black-and-white but was continuous. Two factors appeared to affect *the degree of objectiveness*: number of individuals who confirmed the issue, and reproducibility to confirm the issue. In conclusion, if a specific content of consciousness was reproducibly confirmed by multiple individuals, it could be regarded as objective. According to this conclusion, we raise three neurological premises to objectify the content of consciousness: (1) a *minimally-sufficient content*-specific NCC (mscNCC) exists in the human brain, (2) a specific mscNCC gives rise to a specific content of consciousness, (3) the mscNCC is reproducible among multiple brains. We also raise potential experiments to test these premises.

Introduction

When you are hungry and eat an apple, for example, you would consciously experience something pleasurable. When you are hurt, you would consciously experience something painful. These subjective conscious experiences constitute an essential part of our human life and there is nothing that we know more intimately than the conscious experience. The conscious experience is often called *the content of consciousness* (Koch et al., 2016), and this term appears to mean same concept represented by other expressions by different researchers: conscious experience (Chalmers, 1996), qualia (Ramachandran and Hirstein, 1997; Kanai and Tsuchiya, 2012), phenomenal consciousness (Block, 1995; Cohen and Dennett, 2011), *what it is like* character of experience (Nagel, 1974) or *raw feels* of conscious experience (Ramachandran and Hirstein, 1997). In the present paper, we use the term *the content of consciousness* as synonymous with these other expressions.

Accumulating evidences suggest that the content of consciousness arises from the brain (Click and Koch, 1990; Koch, 2004; Freeman, 2007; Craig, 2009; Dehaene and Changeux, 2011; Lau and Rosenthal, 2011; Tononi and Koch, 2015; Koch et al., 2016). The fact that, while the content of consciousness is subjective and phenomenal, the brain is in nature objective and physical, raises intriguing question *why* the content of consciousness arises from the brain. This question is called the *hard problem* of consciousness as coined by philosopher David Chalmers (Chalmers, 1996), and it remains unclear how this question can be solved.

One of the important steps to answer the hard problem would be to answer *how* the content of consciousness arises from the brain. Scientific methods, in general, have provided most powerful way to answer this kind of *how* questions in nature. Thus, one straightforward idea is to apply scientific methods to answer how the content of consciousness arises from the brain (Armstrong, 1968; Dennett, 1991). This idea has been opposed, however, mainly because, while the content of consciousness is apparently subjective, scientific methods can directly deal with only objective issues but not subjective one (Chalmers, 1996; Velmans, 2007). Indeed, in typical experimental paradigms of both experimental psychology and cognitive neuroscience, the content of consciousness has been indirectly evaluated from the verbal report or from the button-press by participant (subject) (Ress et al., 2000; Super et al., 2001; Tong et al., 2006; Del Cul et al, 2007; Sandberg et al., 2010). Both the verbal report and the button-press (or, more generally, the behavioral report of the content of consciousness), however, rely on the cognitive functions such as attention

(Lamme, 2003; Koch and Tsuchiya, 2007), working memory (Soto and Silvanto, 2014), expectation (Melloni et al., 2011; Kok et al., 2012), introspection, and reportability (Dennett, 1991; Cohen and Dennett, 2011) of which performance themselves can be quite variable among the subjects (Kunimoto et al., 2001). Several studies assessed the contents of consciousness in the absence of behavioral reports from subject by employing decoding of neural signals from subject's brain (Haynes, 2009; Nishimoto et al., 2011; Garcia et al., 2013; Horikawa et al., 2013). Although this approach can solve some aforementioned problems in report-based paradigm, it can hold different problems, such as inclusion of non-conscious neural processing (Tsuchiya et al., 2015). In addition, both report-based method and no-report-based method are limited to measure responses to a simple yes-or-no question (such as "did you see a dot?") in typical experimental paradigms and report/decode only limited information about the content of consciousness of the subject's experiences (Chalmers, 1999). Thus, neither the behavioral reports nor the decoded signals necessarily reflect the full spectrum of the content of consciousness of the subject's experience (Chalmers, 1996; 1999; Velmans, 2007; Koch et al., 2016). The major reason why the content of consciousness cannot be directly dealt in science could be the subjective, non-objective property of the content of consciousness (Chalmers, 2013). Therefore, if it was possible to find a novel way to somehow objectify the content of consciousness, it could be a major breakthrough in consciousness research, leading to scientific direct investigation of the content of consciousness.

In the present paper we will think back how we obtain knowledge in science and what the objectiveness is and show, in the end, an empirical way to objectify the content of consciousness.

Non-objective property makes the content of consciousness non-scientific

It has been proposed that scientific methods can be applied only to objective issues but not to subjective ones, such as the content of consciousness (Chalmers, 1996; 1999; Velmans, 2007). On the other hand, reportability, one of the mental phenomena related to the content of consciousness, for example, has been regarded as an issue of science, even though the reportability itself is just a kind of abstract concepts (the quality of being reportable) and non-objective issue. Then, how objectiveness of mental phenomena such as reportability had been established?

It has been proposed that all questions related to mental phenomena are ones about the performance of *functions* of those phenomena (here, "*function* is used in the sense of any causal role in the production of behavior that a system might perform") (Chalmers, 1996; 2013). In agreement with this proposal, we argue that mental phenomena of interest have been functionally defined in advance to be studied by scientific methods (Fig.1A). This functional defining of mental phenomena have been automatically achieved in most cases, just because, practically, we find and recognize a specific mental function first (reporting something, for example, in case of reportability) and then conceptualize the mental phenomea (reportability, for example). Also, some mental phenomena, such as attention, are defined based on their functions from the first place (Fig. 1B). Then, to explain and obtain knowledge about the mental phenomena, we are just required to clarify the neural mechanism to understand the function of these phenomena (Chalmers, 1996; 2013) (Fig.1A,B). Indeed, the performance of the function of the reportability, for example, can be detected by scientific methods and has enabled us to evaluate the reportability itself. Thus, defining mental phenomena based on their functions has enabled us to evaluate the phenomena in science. Then what is the essential role of the functional defining? We argue that it is the objectification: while reportability itself can't be detected objectively, the function of the reportabiltiy can be detected objectively and scientifically by, for example, verbal report or button press. In other words, the functional defining has objectified the mental phenomena to be ready for scientific investigation (Fig. 1A,B).

The above arguments raise the possibility that the content of consciousness would become an issue in science, if it could be functionally defined (Fig. 1A). However, the content of consciousness is unable to be functionally defined and therefore unable to be objectified at present (Fig.1C), although there are some speculations (Koch, 2004; Lamme, 2006; Freeman, 2007; Seth, 2010). This could be the fundamental reason why it has been so

difficult to deal with the content of consciousness in science.

Then, are there any ways to objectify the content of consciousness without knowledge about their functions? To explore this possibility, we firstly rethink the definition of objectiveness and raise a potential way to objectify the content of consciousness in the following parts.

The content of consciousness can be objectified in theory

Subjective/objective duality has been challenged

Natural science and its viewpoint of the Universe are based on a clear formulation of dualism proposed by Descartes (Descartes, 1644). According to him, the Universe consists of two fundamentally different substances: *res cogitans*, a substance which thinks, and *res extensa*, a substance which extends in space. *Res extensa* is the stuff of which the material world is made, including brains, while *res cogitans* is the stuff of consciousness. Science has developed to deal with only *res extensa*, objective issues, but not *res cogitans*, subjective ones. With this history as a backdrop, it seems to have been widely believed in science community that subjective issues (first-person account) are qualitatively different from and opposed to objective ones (third-person account). This conventional belief of subjective/objective duality seems to prompt many scientists to postulate a clear border between them (Fig. 2A).

It's noteworthy, however, that the definition of subjectiveness and objectiveness has been still controversial. For example, it has been proposed that subjectivity corresponds to the sense of an observing self but not the contents of consciousness (James, 1985; Baars, 1996) while some others has regarded the contents of consciousness as subjective (Nagel, 1974; Chalmers, 1996; Koch et al., 2016). In addition, the belief of subjective/objective duality has been challenged in one of the fields of philosophy called neurophenomenology (Vaerla, 1996). The neurophenomenology states that it becomes less and less obvious how to distinguish between subject and object and that the usual opposition of first-person vs. third-person accounts is misleading (Vaerla, 1996). These arguments prompted us to rethink what we intuitively believed about subjective/objective duality and, in particular, the definition of subjectiveness, objectiveness and their relationship.

Objectiveness is continuous

The definition of subjectiveness and objectiveness seems to be more ambiguous than intuitively believed. When you walk in a park, for example, and count the number of blue birds flying in the park, the number of the birds can be regarded as a kind of data and the data appears to be objective. But, it may become *less* objective if, no one except you was walking around when you counted the birds. It may become *far less* objective if you never saw the birds again in the park in the following days. On the contrary, it may become *more* objective if many people also saw the birds when you counted the birds and both you and others repeatedly observed them many times in the following days as well. In more details,

the data appears to be more objective if you counted the birds with 10 other individuals than you did by yourself. As well, the data appears to be more objective if you saw and counted the birds repeatedly for 20 consecutive days than you did it for only one additional day.

Next, let's think more realistic and scientific situation. The data obtained in scientific studies can be regarded objective and reliable to be published in scientific journals. However, all data published in scientific journals may not necessarily be objective and reliable. In some experiments, for example, multiple researchers performed the same experiments repeatedly and other researchers analyzed the data in a blinded manner, while, in some other experiments, only one researcher performed all the experiments and analyzed the data by himself/herself. One may argue that results obtained in the former cases are more objective and reliable compared to those obtained in the latter case since, in the latter case, some subjective aspects of the researcher who performed all the experiments and the analyses might be included in the resultant data.

Taken together, it appears to be true that objectiveness of a certain issue is not always black and white in nature, but there are some degrees of objectiveness for any issues where, some can represent *low* objectiveness and the others can represent *high* objectiveness. The terms *subjective* and *objective* appear to be located in antipole of the same axis and most subjects appear to be located in between and represent a certain degree of objectiveness (Fig. 2B).

Although the degree of objectiveness of a certain issue seems to be vaguely judged by relevant human community, it is possible that various factors would affect the judgment of the degree of objectiveness of each issue.

Two factors that affect the degree of objectiveness

There appear to be two factors, at least, that affect the degree of objectiveness of the subject of interest: the number of individuals who *confirm* the specific subject, and the degree of reproducibility to *confirm* the subject. The verb *confirm* is used throughout the present paper to represent to be sure and agree to say that something is definitely true. A specific earthquake, for example, which is experienced and confirmed by millions of individuals is highly likely to be regarded objective and thus represents high objectiveness (Fig. 2C, right circle). On the other hands, the one confirmed by only several individuals or just one individual doesn't seem to be regarded objective and thus represents low (Fig. 2C, middle circle) or zero (Fig. 2C, left circle) objectiveness, respectively. This is because the confirmation of an earthquake by only one individual or several individuals could be

explained by, for example, lightheadedness or hallucination, instead of experiencing real earthquake. It's noteworthy that this argument focuses on the specific or an individual earthquake but not the concept of earthquake itself. The concept of earthquake can be regarded objective by the summation of different many experiences in different many individuals. Thus, in general, when we focus on a specific subject, more numbers of individuals who confirmed the subject seem to lead to a judgment of higher degree of objectiveness of the subject.

An earthquake occurs unpredictably when we are not ready. Furthermore, a specific earthquake occurs only one time, so repeated confirmation of a specific earthquake is not possible in nature. On the other hand, an apple on the table, for example, can be confirmed repeatedly whenever we want. This reproducibility is regarded as one of the requirements in science and seems to increase the degree of objectiveness of the subject. Thus, compared to an apple confirmed by several individuals only once, which represents low objectiveness (Fig. 2D, left circle), the same apple on the table confirmed by the same number of individuals but in a reproducible manner seems to be much more objective (Fig. 2D, right circle).

Objectiveness is originally based on subjective experiences and confirmations

Here, it's noteworthy that each individual's experience and confirmation are always achieved subjectively (Vaerla, 1996; Velmans, 1999). When you see an apple on the table and confirm it, for example, you consciously and subjectively do it. When you read and see scientific data on a research paper and confirmed it, you consciously and subjectively do it. Thus, the evaluation of objectiveness of a certain issue is originally based on those subjective experiences or confirmations by each individual who evaluate the issue.

The content of consciousness can be regarded as highly objective in a specific condition

Based on the fact that, each individual's confirmation itself is always achieved subjectively, the above argument "an apple which was confirmed by several individuals in a reproducible manner represents high objectiveness (Fig. 2D)" can be rewritten with more precision as "an apple which was *subjectively* confirmed by several individuals in a reproducible manner represents high objectiveness". This argument can be generalized as "the issue which was subjectively confirmed by several individuals in a reproducible manner represents high objectiveness". According to this generalized argument, even "the content of consciousness can be regarded as highly objective if it was subjectively confirmed by several individuals in

a reproducible manner (Fig. 2E)". It should be noted that this argument does not necessarily deny the subjective aspect of the content of consciousness. In other words, the content of consciousness can become objective while it keeps subjective and phenomenal aspect, similar with a concept of *intersubjective* (Velmans, 1999). To understand subjective/objective aspect of the content of consciousness, it may be helpful to think two-dimensional model (Fig. 2F) instead of one-dimensional model (Fig. 2E).

Taken together, these arguments provide a potential way to objectify the content of consciousness: the content of consciousness can become highly objective if it was reproducibly confirmed by multiple individuals. To test this empirically, we have to establish a quite challenging condition: the specific content of consciousness is reproducibly confirmed by multiple individuals. In the following part, we propose a potential way to empirically establish this condition.

Three neurological premises to objectify the content of consciousness

To objectify the content of consciousness empirically, a specific content of consciousness has to be reproducibly confirmed by multiple individuals. Here we present three neurological premises enough for objectifying the content of consciousness. All the premises are empirically testable and falsifiable (Popper, 2002). In the following part, we explain the three premises and propose possible tests to verify each premise.

Premise 1: Existence of the minimally-sufficient content-specific neural correlate of consciousness (mscNCC)

It's widely accepted that specific neural mechanisms exist in the human brain are sufficient to experience the content of consciousness (Click and Koch, 1990; Koch, 2004; Freeman, 2007; Craig, 2009; Dehaene and Changeux, 2011; Lau and Rosenthal, 2011; Tononi and Koch, 2015; Koch et al., 2016). Koch and his colleagues argue that "the neurons (or, more generally, neuronal mechanisms), the activity of which determines a particular phenomenal distinction within an experience", are the content-specific *neural correlates* of *consciousness* (NCC) (Koch *et al*., 2016). In accordance with their concept, we assumed that a specific content of consciousness would be arisen from a specific neural mechanism that existed in the human brain. To be more precise, we assumed that the neural mechanisms which were minimally sufficient but not necessarily required to generate a specific content of consciousness and named it the *minimally-sufficient content*-specific NCC (mscNCC) (Fig. 3A). When the mscNCC is activated, the subject has to experience the content of consciousness, while, even without the mscNCC, the subject may still experience the content of consciousness. The mscNCC is literally sufficient on it's own to generate the content of consciousness and any other supportive mechanisms are not required. For an extreme example, if the mscNCC was dissected and isolated from the human brain and put in a jar, the mscNCC still generates the content of consciousness in the jar. The mscNCC alone is truly sufficient to generate the content of consciousness in any possible cases and conditions. To ensure minimality of the mscNCC, each neuron, synapse or more generally, neural mechanism consisting the mscNCC has to be tested whether it's activity is indeed required for inducing the content of consciousness.

One of the ways to falsify this premise is to verify that the activation of non-neural mechanisms is sufficient to experience the content of consciousness under the condition where all neural mechanisms are completely inactivated, except for the minimal neural

mechanism required for the survival of the subject, such as the brain stem. In this falsifying test, it is also important to verify that the remained neural mechanism for survival doesn't contain the mscNCC to exclude the possibility that activation of non-neural mechanisms gave rise to the content of consciousness through the indirect activation of the remained neural mechanisms.

In order to empirically find the mscNCC, we need to develop sophisticated methods to activate the neural mechanisms of interest with high spatiotemporal resolution. Although several interesting techniques including optogenetics (Aston-Jones and Deisseroth, 2013) have been developed to manipulate neural activities in non-human animals, their precision would be still not enough to perform experiments demanded here and be required to be far more improved. However, this is just a technical problem and, in principle, this problem is likely to be solved in the future.

Throughout these tests, the content of consciousness itself is subjectively detected by each test participant. The scientists/individuals who want to evaluate the results of experiments containing detection of the content of consciousness are required to join the experiment as participants and need to experience the content of consciousness by themselves. This is in remarkable contrast to other standard scientific research where people can understand experimental results just by evaluating the published data. Thus, the process to confirm the results containing the content of consciousness would be more laborious compared to standard scientific experiments. However, this methodological limitation won't decrease a confidence obtained in each participated researcher who evaluates the results, compared to other standard scientific results, because both methods provide subjective confidence in the end to each individual as well.

One may argue that the premise of the existence of the mscNCC leads to a circular argument: Verification of the three premises may enable the scientific study of the content of consciousness leading to clarify their neural mechanisms, but in order to verify the premises we first need to know what these mechanisms are. This potential argument comes from no distinction between the degree of objectiveness of the content of consciousness before and after the verification of the three premises. Before the verification of the three premises, the content of consciousness is subjective (Fig. 2E, F, left), while this can become highly objective after the verification of all the premises (Fig. 2E, F, right). Thus, the verification of the three premises enables the study of the content of consciousness in more objective manner, and in order to verify all the premises, it's tentatively enough for us to subjectively know the mechanism of the content of consciousness. In other words, subjective knowledge

of neural mechanism of the content of consciousness is tentatively enough to verify the three premises, and if once all the premises were verified, we can conclude that the subjective knowledge can be turned into objective one (discussed below in details).

Premise 2: Specificity of the mscNCC for the content of consciousness

Second premise is that activation of a specific mscNCC gives rise to a specific content of consciousness, but not others (Fig. 3B). While a specific mscNCC should give rise to only one specific content of consciousness, a specific content of consciousness doesn't necessarily arise from only one specific mscNCC. A specific content of consciousness may arise from the multiple different mechanisms (Tononi and Koch, 2015). Also, this second premise does not necessarily mean that a specific mscNCC is completely segregated from other mscNCCs: a part of neural mechanisms of a specific mscNCC may overlap with other mscNCCs.

This second premise would be correct, if the subject continues to experience the specific content of consciousness when a specific mscNCC is kept active, regardless of the activities of *any other mechanisms*. These *any other mechanisms* are defined as in literally all biological mechanisms except for the specific mscNCC of focus. Neural activities of the prefrontal cortex, for example, which is not included in the mscNCC of focus would be among the *any other mechanisms*. One of the ways to falsify this premise is to verify that, even though the specific mscNCC is kept active, the subject stops experiencing the specific content of consciousness when activities of any other mechanisms were changed. Once this premise was verified, the detection of the activity of a specific mscNCC can be regarded as strong empirical evidence for the generation of a specific content of consciousness.

One may argue that this premise is implausible because we know that the content of consciousness is highly sensitive to context: for example, the brightness of two patches, where their absolute luminance is identical, is experienced very differently when they are surrounded by different contexts. However, this case doesn't necessarily mean that a specific mscNCC gives rise to two different contents of consciousness, depending on any other activities. Instead, this case is interpreted as follows: experience of brightness of patch A surrounded by context A is generated by a specific mscNCC, while experience of brightness of patch A surrounded by different context B is generated by a different mscNCC. Thus, different experiences of brightness of the identical patches in absolute luminance surrounded by different contexts are generated by the different mscNCC. Specific stimulus information (luminance of patch) doesn't always activate a specific mscNCC but can activate other mscNCC, depending on other information such as surrounding context.

Premise 3: Reproducibility of the mscNCC

Third premise is that a specific mscNCC can be reproduced among multiple individuals (Fig. 3C). In order to test whether a specific mscNCC can be reproduced among multiple individuals, we firstly need to develop novel and sophisticated technologies to reproduce the mscNCC in multiple brains. For example, if the essential neural mechanisms of the mscNCC are governed by the specific activity patterns in specific neural networks, the same patterns of activation should be reproduced in other brains. With this idea, unambiguous confirmation of identicalness of the mscNCC replicated in different brains could be crucial. For this empirical confirmation, detailed identification of the neural mechanisms of the mscNCC, e.g., specific neural or synaptic activity pattern, in advance would be crucial. Recent development of non-invasive human brain-to-brain interface (Yoo et al., 2013; Lee et al., 2017; Mashat et al., 2017) may be a potential way to share some neural mechanisms among multiple individuals, it might be only a matter of time but present precision appears to be still not enough to perform experiments demanded here.

To test whether the specific mscNCC is truly reproduced or not, it is necessary and sufficient to show that the specific mscNCC of one participant is also the mscNCC of others. First we should test whether a specific mscNCC of interest is the minimal neural mechanism which is sufficient to give rise to a specific content of consciousness in each participant. Here, empirical confirmation of identicalness of the content of consciousness experienced by different participants is not required. The identicalness of the specific mscNCC manipulated experimentally, but not the identicalness of the content of consciousness experienced by each participant, is important in this reproduction test. Indeed, we naturally realize that it's impossible to directly compare the content of consciousness of different participants, and, again, this comparison is not required in this test. We should focus on whether the identical mscNCC gives rise to a specific content of consciousness in each subject and we don't need to care, during this reproduction test, whether the mscNCC gives rise to identical content of consciousness in each participant (you would understand its reason afterwards).

One of the ways to falsify this reproduction premise is to verify that the participant does not experience any content of consciousness regardless of the activation of the potentially reproduced neural mechanisms of which activation gives rise to specific content of consciousness in other participants.

One may argue that it's not clear how we can be sure that all of the contents of consciousness are contained only in the part that is reproduced in multiple participants. We

do not insist that all of the contents of consciousness should arise only from the reproduced part. The reproduced mscNCC may give rise to only specific content of consciousness, such as red color or black line, but not others. We believe that a single pair of the specific mscNCC and the specific content of consciousness is tentatively enough for the reproduction test.

The content of consciousness can represent high objectiveness if aforementioned three premises were verified

If aforementioned three premises were verified, the reproduced mscNCC in multiple brains (premise 3) should give rise to identical content of consciousness in multiple individuals (Fig. 3D), because activation of a specific mscNCC give rise to a specific content of consciousness regardless of background activity of any other mechanisms (premise 2) (Fig. 3B). Here, the identical content of consciousness shared among multiple individuals can be regarded as intersubjective and represent high objectiveness, because it is subjectively confirmed by multiple individuals in a reproducible manner (Figs. 2E,F and 3D).

One may argue that it's not clear how we can be sure that the content of consciousness among multiple participants is not different from each other by the influence of surrounding neural activities which are not reproduced among them. This argument seems to come from misunderstanding of premise 2. The premise 2 assumes that activation of a specific mscNCC gives rise to a specific content of consciousness regardless of the activities of any other mechanisms (Fig. 3B). Even if neural activities which are not reproduced among participants are different among participants, it doesn't influence the specifc-mscNCC-induced content of consciousness experienced by participants, because an activation of the specific mscNCC gives rise to a specific content of consciousness regardless of any other neural activities (premise 2).

Others may argue that we need to demonstrate that the shared content of consciousness is indeed identical among multiple individuals. As mentioned above, identicalness of the content of consciousness among multiple individuals is a logical consequence of the fulfillment of premises 2 and 3: a specific mscNCC gives rise to a specific content of consciousness regardless of any other activities (premise 2) and the identical mscNCC is reproduced among the multiple participants (premise 3). Therefore, identicalness of shared content of consciousness among multiple individuals is guaranteed by logic without direct empirical detection of the content of consciousness itself.

Discussion

We argue that a content of consciousness can become objective if it was reproducibly confirmed by multiple individuals. To test this argument, we need to establish the condition that a content of consciousness is reproducibly confirmed by multiple individuals. One potential way to establish this condition is to empirically verify the three neurological premises about the properties of the neural basis of the content of consciousness: (1) an mscNCC is exist in the human brain, (2) a specific mscNCC gives rise to a specific content of consciousness, (3) the mscNCC is reproducible among multiple brains. All these three premises are empirically falsifiable, ensuring that these premises would be scientific (Popper, 2002). The present paper illustrates a potential way to objectify the content of consciousness without knowledge about its function. This possibility, to our knowledge, hasn't been well discussed so far, probably just because it has been intuitively believed impossible.

Objectiveness of a certain issue appears to be vaguely judged by human society

We raised two factors that appear to affect the degree of objectiveness of a certain issue (Fig. 2). The objectiveness of a certain issue seems to have been vaguely judged by a certain human community. At present, it remains unclear which society or people judge the objectiveness of the content of consciousness when above-mentioned three premises were empirically verified. It seems to be important to establish a standard to judge the degree of objectiveness of a certain issue of interest with agreements of relevant human societies.

mscNCC appears to be included in the Chalmers' NCC (for content)

We defined an mscNCC as the neural mechanisms which are minimally sufficient to generate a specific content of consciousness under any possible cases or conditions (Fig. 3). Chalmers, on the other hand, had defined an NCC for the content of consciousness as follows: "An NCC (for content) is a minimal neural representational system *N* such that representation of a content in *N* is sufficient, under condition *C*, for representation of that content in consciousness" (Chalmers, 2000). The minimality-constraint and mere-sufficiency-constraint appear to be shared between our mscNCC and the Chalmers' NCC (for content) (Chalmers, 2000). One clear difference is that the mscNCC generates a content of consciousness under any possible cases or conditions, while the Chalmers' NCC (for content) doesn't specify the condition under which an NCC generates a content of consciousness. Chalmers argued that "the precise nature of condition *C* is still debatable"

and raised five possible cases (Chalmers, 2000). One of the five possible cases, "(B1) Any possible case", in his paper (Chalmers, 2000), appears to correspond to a case of mscNCC. Therefore, mscNCC appears to be regarded as a specific case of the Chalmers' NCC (for content).

Nagel's question can be answered, and both 'Inverted Qualia' and 'Philosophical Zombie' can be denied

If a content of consciousness was reproduced in multiple individuals, we would have an answer for Nagel's famous philosophical question: "what is it like to be a bat?" (Nagel, 1974). Simply, this Nagel's question claimed that "to know whether you, the reader, are conscious, I must know what it is like to be you (Baars, 1996)". This demands that an observer (experimenter) should somehow share the contents of consciousness of the subject (participant) (Baars, 1996). This could be achieved if an mscNCC was found (premise 1), a specific mscNCC gives rise to a specific content of consciousness (premise 2), and an identical mscNCC was reproduced between the observer (experimenter) and the subject (participant) (premise 3): in this situation, the observer (experimenter) would share, in theory, exactly identical content of consciousness with the subject (participant) and know what it is like to be the subject. As well, in this situation, we can deny the possibility that the observer (experimenter) and the subject (participant) experience *Inverted Qualia* (Shoemaker, 1982; Block, 1990) since they share identical content of consciousness. We can also deny another possibility that the subject (participant) is *Philosophical Zombie* (Chalmers, 1996) since the subject (participant) experiences identical content of consciousness experienced by the observer (experimenter).

Consciousness can be separated from function

It have been claimed that consciousness cannot be separated from function and that it is impossible to prove the existence of consciousness independent of function and access (Dennett, 1991; 2001; Cohen and Dennett, 2011). This view is now challenged. It would be widely acceptable that a specific content of consciousness can be subjectively experienced by the subject himself/herself independent of function and access. According to our aforementioned conclusion, the specific content of consciousness can be regarded as objective if it was reproduced in multiple individuals (Fig. 2). Thus, the content of consciousness can be separated from function, and the existence of the content of consciousness independent of function and access can be objectively proved. In theory, the mechanisms of the content of

consciousness can be objectively investigated independent of cognitive functions through empirical objectification of the content of consciousness (Fig. 4, bottom).

Some obstacles in first-person data can be leaped

First-person data appear to contain something which is excluded in both heterophenomenology (Dennett, 1991; 2001) and critical phenomenology (Velmans, 2007) but is of central importance to the nature of the content of consciousness. However, first-person data is accompanied with three obstacles, *Privacy*, *Methods* and *Formalisms* (Chalmers, 2013) when it is tried to be used in science of consciousness. *Privacy* claims that first-person data concerning subjective experiences are directly available only to the subject having those experiences and only indirectly available to others (Chalmers, 2013). However, if a specific experience (content of consciousness) of one person is reproduced in others, first-person data concerning subjective experience can be directly available to others, so those data are not private at all. *Methods* claim that current methods for gathering first-person data are quite primitive (Chalmers, 2013). However, in the present objectification process (Fig. 3,4), it is not required to gather first-person data since it can be directly experienced and presented to others. *Formalisms* claim that general formalism to express first-person data is lacking, and this is required for data gathering and theory construction (Chalmers, 2013). However, in the present objectification process (Fig. 3,4), gathering of first-person data is not required as discussed above, so formalism for this is not required as well. On the other hand, the development of a certain formalism may be required to write down any conclusions of the experiment conducted during the present objectification process (Fig. 3,4) and to describe a theory explaining relationship between the content of consciousness and neural mechanisms. Therefore, empirical objectification of the content of consciousness (Fig.3,4) may overcome several obstacles involved in first-person data (Chalmers, 2013) and open the way for first-person methods in science of consciousness.

The "hard problem" is left hard

Chalmers has raised a so-called *hard problem*: *why* the content of consciousness arises from the brain (Chalmers, 1996). Even if the content of consciousness was objectified and its neural mechanism was scientifically resolved (Fig. 4), it would be still not enough to answer that kind of *why* question. Instead, what we can answer is *how* the content of consciousness arises from the brain and which neural mechanisms give rise to the content of consciousness (Koch et al., 2016).

Does empirical objectification make the content of consciousness a direct target of science?

Even if the content of consciousness was objectified, it may still be controversial whether the objectified content of consciousness could be a target of science. A most clear methodological difference between *standard* science and experiments including the objectified content of consciousness is that, while data obtained in ordinary science can be described and evaluated by a third person, the experiments including the objectified content of consciousness can not. It is noteworthy, however, that the third person can understand and evaluate the objectified content of consciousness when he/she joins the experiment and experience the shared content of consciousness by himself/herself. As has been clear, however, the third person who joined the experiments isn't a third person anymore. Velmans has argued that shared experiences among multiple individuals may be *public and objective* (Velmans, 1999). "To the extent that an experience… can be *generally* shared (by a community of observers), it can form part of the data base of a communal science" (Velmans, 1999). More discussions in science community may be needed to determine whether this methodological demand or limitation can be acceptable as a kind of novel scientific methods or not. If this novel first-person method was accepted as one of scientific methods, the empirical objectification could pave the way for scientific investigation of the content of consciousness (Fig. 4).

Conclusion

At present, we neuroscientists don't have any methodology to directly investigate our subjective conscious experience, the content of consciousness. This limitation has hampered us to directly deal with the content of consciousness as subjects of neuroscience. In the present paper, we argue that the content of consciousness can become objective in principle. We propose one potential way to empirically objectify the content of consciousness. Successful objectification of the content of consciousness depends on not only the results of raised tests but also a final judgment of relevant human society which determines the objectiveness of certain issues. We believe that we neuroscientists can directly deal with the content of consciousness and its underlying neurological mechanisms in the future.

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Legends

Figure 1

Mental phenomena excluding content of consciousness have been objectified based on their functions in advance to be studied in science.

(**A**) Mental phenomena like reportability and working memory which are not defined by their functions have been objectified through functionalization. To obtain knowledge about mental phenomena in science, mechanisms of the function of the mental phenomena of interest have been identified (right). To identify the mechanisms, the functions of the phenomena, which are concrete targets to be studied, need to be identified (middle). This identification of function has been automatically achieved in most mental phenomena without experimental efforts, since, practically, we find and recognize a specific mental function first (reporting something, in case of reportability, for example), and then we conceptualize related matters.

(**B**) Mental phenomena which are defined by their functions are objective from the first place and can be a target directly in science.

(**C**) The content of consciousness had not been able to be defined based on their functions and thus it had been difficult to be objectified in a normal way in science (crosses). This could be the fundamental reason why it has been impossible to deal with the content of consciousness directly in science.

Figure 2

The content of consciousness can be highly objective in a specific condition.

(**A**) A conventional *separated* view of the relationship between the terms *subjective* and *objective* in science. It is believed that subjective things are qualitatively different from objective ones, and there is a clear border between them.

(**B**) A novel *continuous* view of the relationship between the terms *subjective* and *objective*. The *subjective* and *objective* appears to be located in the antipole of the same axis and objectivity is continuous. Most subjects appear to be located in between and all represent a certain degree of objectiveness.

(**C**) More numbers of individuals who confirmed the subject would guarantee higher degree of its objectiveness. A specific earthquake which is experienced by millions of individuals is highly likely to be regarded objective and thus represents high objectiveness (right circle). The one experienced by only several (middle circle) or one (left circle) individuals may not be

regarded objective and thus represents low or almost-zero objectiveness, respectively, because the experiences of an earthquake in only several or one individuals could be explained by something other than real earthquake experience, such as lightheadedness or hallucination. Note that the real earthquake experienced and confirmed by individuals are through not only somatosensory detection of the earthquake itself but also visual and auditory experiences of shaking of the surrounding objects by the earthquake. Observation of the affected objects by the earthquake can be further additional evidence to judge the occurrence of the earthquake.

(**D**) Reproducibility would increase objectiveness of the subject. An apple confirmed by several individuals in a reproducible manner appears to represent higher objectiveness (right circle) compared to the same apple confirmation by the same number of individuals only one time (left circle).

(**E**) The content of consciousness can be objectified in a specific condition. A specific content of consciousness in usual situation, that is, a content of consciousness experienced by one individual once seems to be absolutely subjective and represents zero for objectiveness (left circle). If a specific content of consciousness was confirmed by several individuals in a reproducible manner, the content of consciousness could be regarded as highly objective (arrow and right circle).

(**F**) Same with **E** but represented in two-dimensional model of subjective/objective relationship. Even if the content of consciousness was reproducibly confirmed by multiple individuals and regarded as highly objective, the subjective and phenomenal aspect of the content of consciousness in each individual is likely to be maintained. This point may be better represented in two-dimensional model compared to one-dimensional model (E), although, from the first place, it may be required to rethink more deeply the definition of the term *subjective* and *objective* in advance to discuss about this topic in depth.

Figure 3

Schema of the three neurological premises and a resultant logical consequence when the three premises were verified.

(**A**) Premise 1: existence of the content-specific and sufficient neural correlates of consciousness (mscNCC) which is defined as the minimum neural mechanisms jointly sufficient (but not necessarily required) to experience a specific content of consciousness.

(**B**) Premise 2: specificity of the mscNCC for the content of consciousness. Activation of a specific mscNCC gives rise to a specific content of consciousness, but not others, regardless of the background activity of any other mechanisms.

(**C**) Premise 3: reproducibility of the mscNCC. The mscNCC can be reproducible among multiple brains.

(**D**) A logical consequence when the three premises (**A**-**C**) were verified. When the mscNCC which gives rise to an experience of a heart symbol in person *a* is identical with the mscNCC of person *b*, the mscNCC can be regarded as the duplicated mscNCC between person *a* and *b*. The activation of the duplicated mscNCC should induce identical experience of a heart symbol to both person *a* and *b* as a logical consequence of the premises 2 and 3. In other words, the experience of a heart symbol can be shared between person *a* and *b*. Thus, the shared experience of a heart symbol (or, more generally, the content of consciousness) is intersubjective and can be regarded as objective, because the shared content of consciousness is subjectively confirmed by multiple individuals in a reproducible manner (**Fig. 2E,F**).

mscNCC, minimally-sufficient content-specific neural correlates of consciousness

Figure 4

Schema illustrating empirical objectification of the content of consciousness.

Empirical objectification of the content of consciousness (blue arrow) can enable us to directly deal with the content of consciousness in science and obtain knowledge about its underlying mechanisms. Also see Figure 1 in comparison.

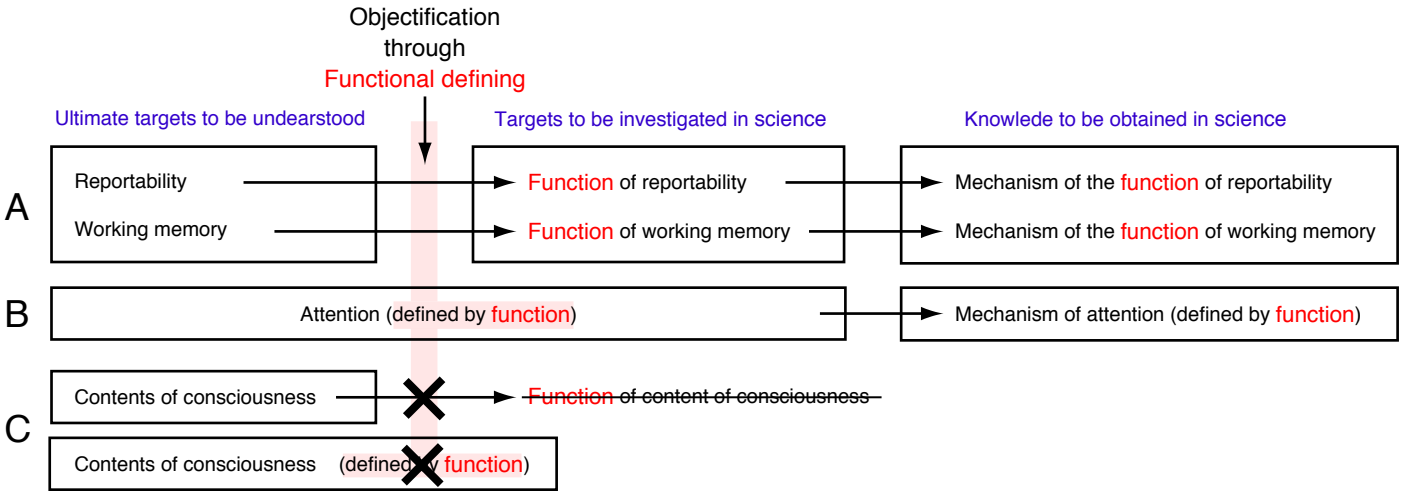
Objectification
through
Functional defining
Ultimate targets to be undearstood
Targets to be investigated in science
Knowlede to be obtained in science
A
Reportability
Working memory
Function of reportability
Function of working memory
Mechanism of the function of reportability
Mechanism of the function of working memory
B
Attention (defined by function)
Mechanism of attention (defined by function)
C
Contents of consciousness
Function of content of consciousness
Contents of consciousness (defined by function)

Figure 1

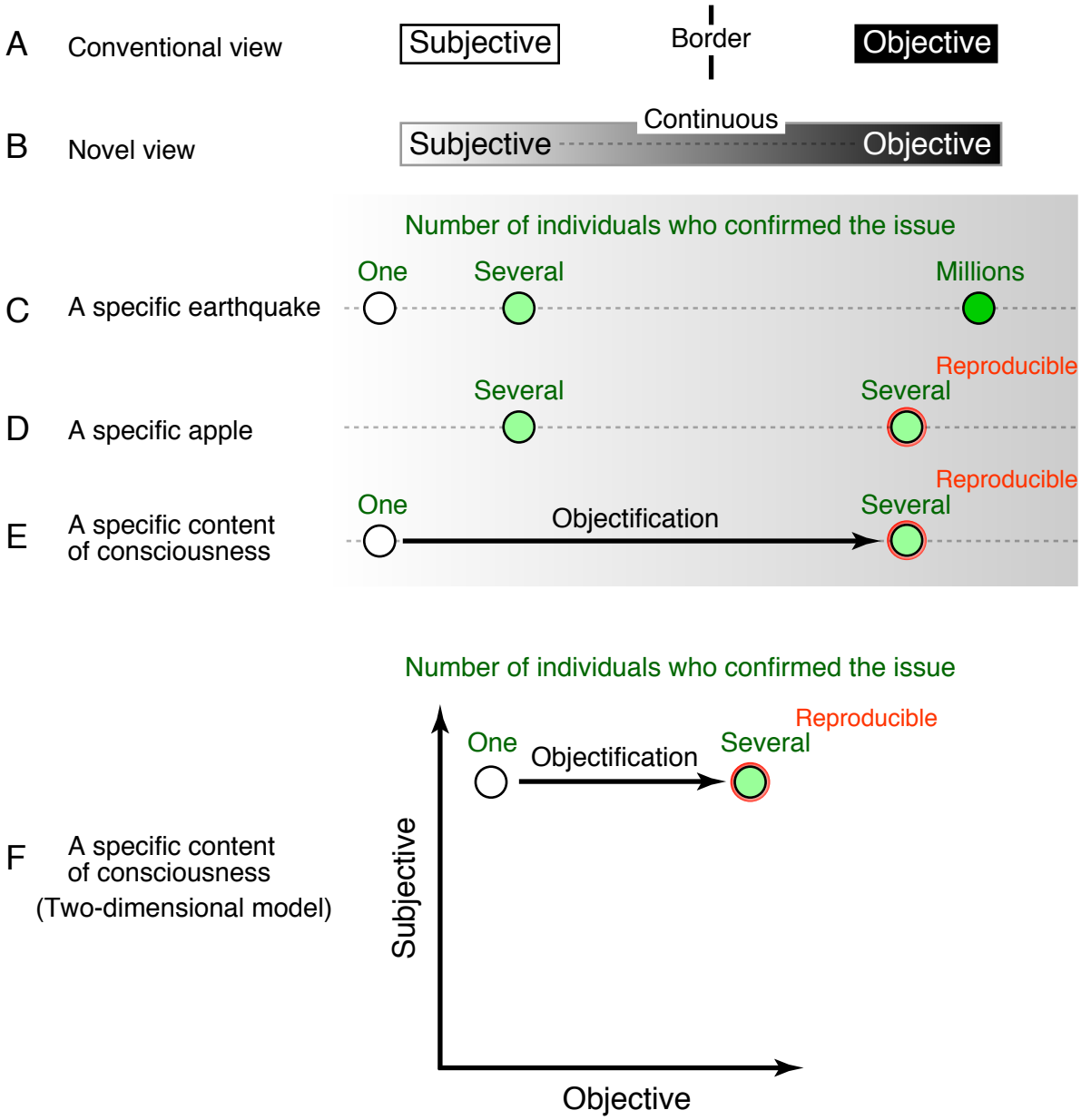
A
Conventional view
Subjective
Border
Objective
B
Novel view
Continuous
Subjective
Objective
Number of individuals who confirmed the issue
One
Several
Millions
C
A specific earthquake
Reproducible
Several
Several
D
A specific apple
Reproducible
One
Objectification
Several
E
A specific content
of consciousness
Number of individuals who confirmed the issue
Reproducible
One
Objectification
Several
F
A specific content
of consciousness
(Two-dimensional model)
Subjective
Objective

Figure 2

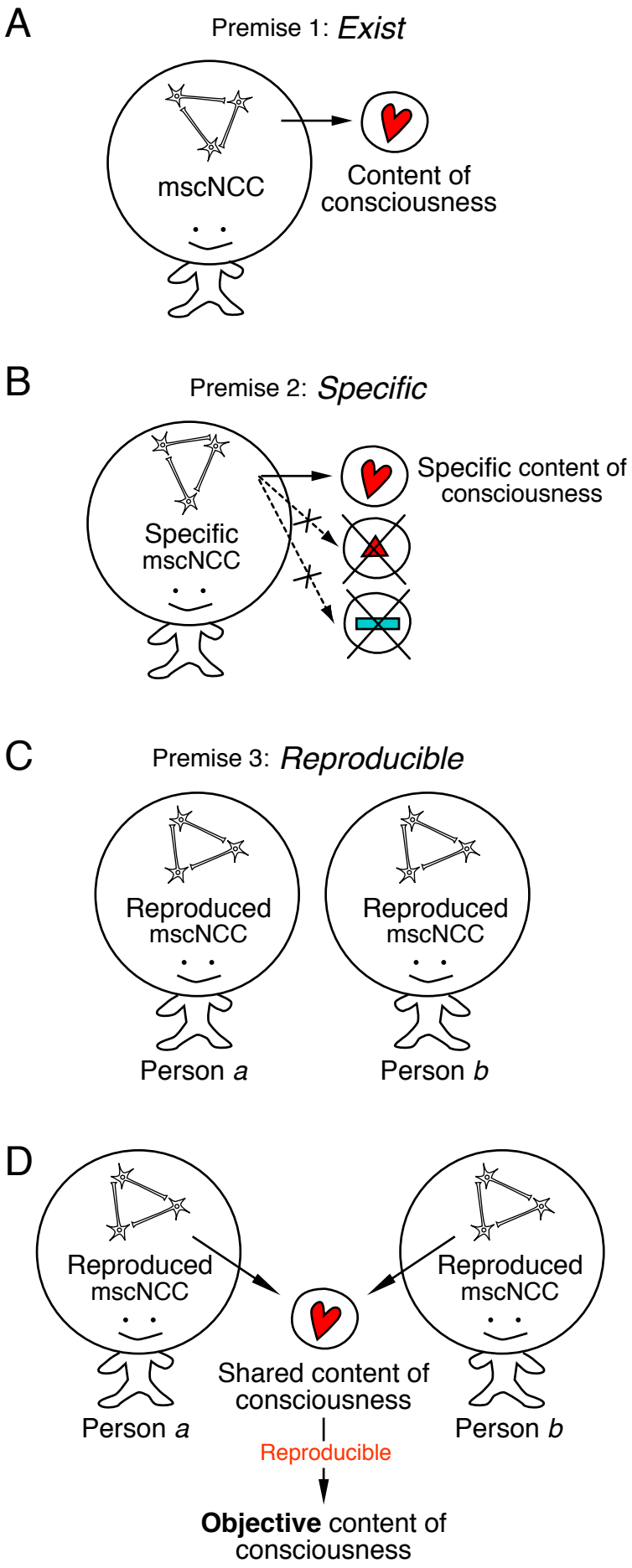
A
Premise 1: Exist
mscNCC
Content of consciousness
B
Premise 2: Specific
Specific mscNCC
Specific content of consciousness
C
Premise 3: Reproducible
Reproduced mscNCC
Reproduced mscNCC
Person a
Person b
D
Reproduced mscNCC
Reproduced mscNCC
Shared content of consciousness
Person a
Person b
Reproducible
Objective content of consciousness

Figure 3

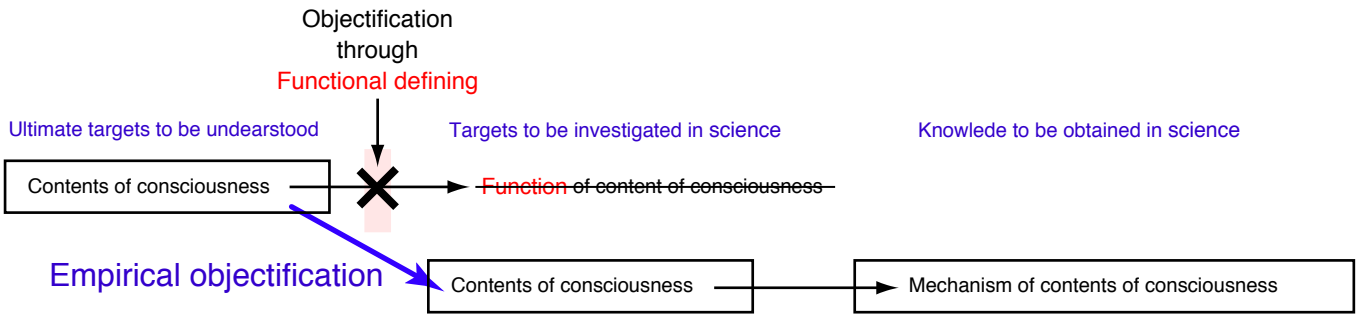
Objectification
through
Functional defining
Ultimate targets to be undearstood
Targets to be investigated in science
Knowlede to be obtained in science
Contents of consciousness
Function of content of consciousness
Empirical objectification
Contents of consciousness
Mechanism of contents of consciousness

Figure 4