CHANCE: a method that enables a researcher to fully know the content of consciousness of a subject in scientific experiments

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Abstract

The content of consciousness (cC) constitutes an essential part of our human life and the very heart of the *hard problem* of consciousness. In science, the cC of a subject (participant) has been examined *indirectly* through measuring his/her behavioral reports, bodily signs, or neural signals. None of them, however, reflects the full spectrum of the subject's cC, hampering a researcher to fully know the subject's cC and find its neural basis precisely and extensively. Here we propose a method, termed CHANCE that enables a researcher to experience and know *directly* the full spectrum of the subject's cC in scientific experiments. The degree of epistemic objectivity of a specific entity has been reasonably judged by relevant individuals who have the ability to judge the faithfulness of the entity to the truth (the true facts). More number of relevant individuals who judge the entity as the truth results in more objectivity of the entity epistemically. Thus, even the knowledge of a specific cC itself would be regarded as epistemically objective if it was judged as the truth (being truly had) by multiple relevant individuals. We propose CHANCE consisting of three empirical steps to change the knowledge of the cC itself from epistemically subjective to objective: (1) finding a *minimally-sufficient content-knowledge-specific neural correlates of consciousness* (msckNCC), and (2) selecting an msckNCC that produces the knowledge of only one specific cC but not others, and finally, (3) among the msckNCCs that verified the 2nd step, selecting an msckNCC that is reproducible in multiple brains.

Introduction

When you are hungry and eat an apple, for example, you would consciously experience something pleasurable. When you get hurt, you would consciously experience something painful. These subjective conscious experiences constitute a core part of our human life and are central to a proper understanding of the nature of consciousness (Chalmers, 1995; Tye M, 2018). The conscious experience is often called *the content of consciousness* (cC) (Koch et al., 2016), and this term appears to mean similar concept represented by other terms: qualia (Peirce, 1866/1982), phenomenal property of experience, *what it is like* property of experience (Nagel, 1974) or raw feels of conscious experience (Ramachandran and Hirstein, 1997). In the present paper, we use the term the cC as synonymous with these terms.

The cC arises at least from human brain (Click and Koch, 1990; Koch, 2004; Freeman, 2007; Craig, 2009; Dehaene and Changeux, 2011; Lau and Rosenthal, 2011). While the cC is ontologically subjective and qualitative, the brain is in nature ontologically objective and physical, raises intriguing question how the cC arises from the brain, which is called the *hard problem* of consciousness (Chalmers, 1996). Numerous scientific studies have been done in both experimental psychology and cognitive neuroscience in order to reveal the neural basis of the cC, and they have made great progress. In their typical experimental paradigms, the cC of a subject (participant) has been examined *indirectly* through his/her verbal report or button press (Ress et al., 2000; Lutz et al., 2002; 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 reports of the subject's cC), 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). Thus, the behavioral reports do not fully reflect the subject's cC. In addition, in such report-based paradigm, the possible neural bases that produce the cC can not be separated from that underlying reportability (Cohen and Dennett, 2011), suggesting that, even if researchers established a behavioral report that fully reflected the subject's cC, it would be impossible to indentify the minimal neural basis that produce the cC to the extent that report-based paradigm was used. Several studies assessed the cC through bodily signs, such as pupil size (Frassle et al., 2014), or by neural decoding (Haynes, 2009; Nishimoto et al., 2011; Garcia et al., 2013; Horikawa et al., 2013) in the absence of behavioral reports. Although these approaches can overcome some aforementioned problems in the report-based paradigm, it can have different problems, such as missing some percepts due to no-report or inclusion of non-conscious neural processing (Tsuchiya et al., 2015). Thus, neither the bodily signs nor neural signals fully reflect the subject's cC. In addition, both report-based and no-report-based paradigms are limited to measure responses of a subject to a simple question (such as "did you see a dot?") in typical experimental paradigms and report/decode only limited information about the subject's cC. Therefore, none of the behavioral reports, the bodily signs, and the neural signals reflects the full spectrum of the subject's cC (Nagel, 1974; Chalmers, 1996; 1999; Velmans, 2007), hampering a researcher to know it. Also, the fact that only limited information about the subject's cC is available with current methods often makes it difficult to deal with the cC which appears to be essential for human life but beyond any reports, signs and signals, such as a feeling of self and a raw feeling of well-being. Therefore, it is important for researchers to develop a novel method to know the subjects' cC more closely to find its neural basis more precisely and extensively.

Here we propose a method, termed *CHANging Consciousness Epistemically* (CHANCE) that enables a researcher to experience and know *directly* the full spectrum of the subject's cC in scientific experiments.

The knowledge of the cC itself can be changed from epistemically subjective to objective in theory

Epistemic objectivity comes in degrees

Science has developed to deal with epistemically objective entities but not subjective ones (Galileo, 1623; Descartes, 1644; Chalmers, 1996, 1999; Searle, 1998; Velmans, 2007). With this history as a backdrop, many scientists appear to believe that epistemically subjective entities are qualitatively different from and opposed to objective ones and draw boundaries between them (Tye KM, 2018). However, the epistemic subjective-objective distinction appears to be more blurred than that intuitively believed by many scientists. In a science laboratory, for example, an experiment was performed repeatedly by multiple researchers to obtain a datum, while, in another laboratory, the same experiment was performed only once by one specific researcher. Hopefully, most researchers would agree that, although the both datum obtained in each laboratory may be regarded as epistemically objective and available in science, the datum obtained in the former laboratory can be more faithful to the true facts (the truth) and thus more objective epistemically compared to that obtained in the latter one. This is because, in the latter case, the datum might be obtained just by chance and/or some subjective aspects of the specific researcher, such as a personal belief or preference, might bias the datum obtained. Thus, the epistemic objectivity of a datum (or, more generally, entity) is not always all or nothing, but there are some degrees of objectivity for any entities where, some can be less objective and the others can be more objective (Reiss and Sprenger, 2017). In the epistemic sense, the terms *subjective* and *objective* appear to be located in antipole of the same axis and most entities are located in between and have some degree of objectivity.

The degree of epistemic objectivity of an entity has been reasonably judged by relevant individuals who have the ability to judge the faithfulness of the entity to the truth (the true facts) (Reiss and Sprenger, 2017). In case of scientific results, for example, the faithfulness of the results to the truth and its degree of epistemic objectivity has usually been judged by leading scientists in the relevant research field (reviewers of the relevant journals). In case of an apple on the table, not only scientists but also others may be able to judge its faithfulness to the truth and epistemic objectivity. Depending on the focused entity, relevant individuals who can judge its epistemic objectivity appear to change, and various factors appear to affect the judgment.

More number of relevant individuals who judge the entity as the truth results in more objectivity of the entity epistemically

There is at least one factor that appears to affect the degree of epistemic objectivity of a specific entity: the number of relevant individuals who judge the entity as the truth. A experimental result, for example, which is judged as the truth by tens of experts appears to be regarded as faithful to the truth and epistemically objective, while the one judged as the truth by only one appears to be regarded as not faithful to the truth and not objective epistemically. A specific thunder, for example, which is observed and judged as the truth (truly happening) by hundreds of individuals appears to be regarded as faithful to the truth and epistemically objective, while the one judged as the truth by only one appears to be regarded as not faithful to the truth and not objective epistemically. In general, more number of relevant individuals who judged the entity as the truth leads to a judgment of more faithfulness of the entity to the truth and thus more objectivity of the entity epistemically. This argument is consistent with a philosophical argument, *intersubjective agreement*: agreement in different subjects' judgments is often taken to be indicative of objectivity (Steup, 2018). Taken together, a specific entity would be regarded as epistemically objective if it was judged as the truth by multiple relevant individuals.

Epistemic objectivity is necessarily based on ontologically subjective knowledge and judgments.
Each individual's judgments are always achieved subjectively (Vaerla, 1996; Velmans, 1999) in the ontological sense. When you see an apple on the table and judge it as the truth (truly existing), for example, you consciously and subjectively do them in the ontological sense. When you observe experimental results or see scientific data on a research paper and judge them as the truth, you consciously and subjectively do them in the ontological sense. According to the *indirect realism*, while we know *what they are like* directly, we know external objects indirectly based on our knowledge of sense data (Steup, 2018). Thus, the epistemic objectivity of a specific entity is necessarily based on ontologically subjective knowledge and judgments by each individual who examines the entity.

The knowledge of the cC can be regarded as epistemically objective in a specific condition
Based on the fact that, each individual's judgment itself is always achieved subjectively in the ontological sense, the above argument "a specific entity would be regarded as epistemically objective if it was judged as the truth by multiple relevant individuals" can be revised to "a specific entity would be regarded as epistemically objective if it was *subjectively* judged as the truth *in the ontological sense* by multiple relevant individuals". According to this argument, even "the knowledge of the cC itself would be regarded as epistemically objective if it was *subjectively* judged as the truth (being truly had) *in the ontological sense* by multiple relevant individuals". This last argument provides an intriguing idea to empirically change the knowledge of the cC itself from epistemically subjective to objective: the knowledge of the cC itself can become epistemically objective if it was subjectively judged as the truth (being truly had) in the ontological sense by multiple relevant individuals (Figure 1b). Notably, this idea to change the knowledge of the cC itself from epistemically subjective to objective (Figure 1b) shows sharp contrast with the former, ordinal way in the scientific studies of the cC (Figure 1a). In all, to our knowledge, previous scientific studies of the cC, the behavioral reports, bodily signs, or neural signals were used as "readouts" of the subjects' cC (Figure 1a, red arrow). Then the measures of the readouts were judged as the truth by multiple relevant individuals and recognized as epistemically objective and scientific data (Figure 1a). Thus, in all previous scientific studies, the subject's cC was *indirectly* examined through measuring its readouts. The problem is that none of the readouts reflects the full spectrum of the subject's cC. If the knowledge of the subject's cC itself was changed from epistemically subjective to objective as we proposed, it would be able to be examined *directly* in science (Figure 1b) (Searle 1998).

To change the knowledge of the cC itself from epistemically subjective to objective, we have to establish a quite challenging condition: the knowledge of the cC itself is subjectively judged as the truth (being truly had) in the ontological sense by multiple relevant individuals (Figure 1b). In the following section, we propose a method to empirically establish this condition.

CHANCE: a method to change the knowledge of the cC itself from epistemically subjective to objective
We propose a method, termed CHANCE that enables the knowledge of a specific cC to be subjectively judged as the truth (being truly had) in the ontological sense by multiple relevant individuals and to be changed from epistemically subjective to objective (Figure 1b). CHANCE constitutes three steps: (1) finding a *minimally-sufficient content-knowledge-specific neural correlates*

of consciousness (msckNCC), and (2) selecting an msckNCC that produces the knowledge of only one specific cC but not others, and finally, (3) among the msckNCCs that verified the 2nd step, selecting an msckNCC that is reproducible in multiple brains. In the following part, we explain the three steps of CHANCE in order.

First step: finding a minimally-sufficient content-knowledge-specific neural correlates of consciousness (msckNCC)

The specific neural bases in human brain are sufficient to produce a cC (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). Chalmers defines an NCC for a cC 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). Inspired by their concepts, we assume a neural event which is minimally sufficient to produce the knowledge of a cC without any other supportive mechanisms and name the event the *minimally-sufficient content-knowledge*-specific NCC (msckNCC) (Figure 2a). When an msckNCC occurs in the brain of a subject (participant), the subject should experience and know a cC in any possible cases and conditions, while, even without the msckNCC, the subject may still experience and know the cC by neural events other than the msckNCC. An msckNCC is literally *sufficient* on it's own to produce the knowledge of a cC without any other supportive mechanisms. This point appears to be in contrast with the above Chalmers' NCC (for content) (Chalmers, 2000). Chalmers claims that "Nobody (or almost nobody) holds that if one excises the entire inferior temporal cortex or intralaminar nucleus and puts it in a jar, and puts the system into a relevant state, it will be accompanied by the corresponding state of consciousness" (Chalmers, 2000). We claim that if an msckNCC was isolated from human brain and put in a jar, the msckNCC would still produce the knowledge of a cC in the jar. That is, an msckNCC alone is truly *sufficient* on it's own to produce the knowledge of a cC in any possible cases and conditions. Also, to ensure minimality of an msckNCC, each neuronal, synaptic, and molecular event, or more generally, neural event consisting the msckNCC should be tested whether it is indeed required to produce the knowledge of a cC.

One (Chalmers, maybe) may argue that nobody in consciousness science, except for proponents of panpsychism (Tononi and Koch, 2015; Koch et al., 2016), would think that "if an msckNCC was isolated from human brain and put in a jar, the msckNCC would still produce the knowledge of a cC in the jar". Probably this argument largely originates from just intuition or common sense. Hopefully, most consciousness researchers would agree with that, if a whole human brain was put in a jar and activated appropriately, the brain would produce the knowledge of a cC in the jar. In this condition, not all neural events in the brain would be required to produce the knowledge of the cC. Those unnecessary neural events can be removed from the brain. If this removal of unnecessary events was repeated again and again, then, in the end, only an msckNCC would be remained in the jar and it "would still produce the knowledge of a cC in the jar".

In order to empirically find an msckNCC, while the neural events of focus need to be empirically induced with high spatiotemporal resolution, the effects of the induction on the knowledge of a cC need to be subjectively experienced in the ontological sense by a researcher/subject who wants to evaluate the effects (Figure 2a). Thus, the brain of a researcher/subject who wants to evaluate the results needs to be empirically manipulated in this experiment. The results obtained in this experiment would be the knowledge of a cC which is ontologically subjective and only available to a researcher/subject whose brain was manipulated, and thus epistemically subjective. That is, this experiment would contain epistemically subjective results and thus be regarded as non-scientific. However, this methodological limitation won't decrease a confidence obtained in each participant who evaluates the cC-containing results, compared to standard scientific results, because both methodologies would provide ontologically subjective knowledge, confidence and judgment in the end to each individual as well. The neural events of focus would be concluded as an msckNCC if following two conditions were verified: (1) a researcher/subject whose brain was manipulated had the knowledge of a cC when the neural event of focus was specifically induced while *any other neural* *events* were completely inhibited (verification of *sufficiency*); (2) a researcher/subject whose brain was manipulated did not have the knowledge of a cC when any one neural event among the all focused events was inhibited (verification of *minimality*).

One may argue that it is not realistic to verify the above two conditions to find an msckNCC. Indeed, it is very challenging to develop techniques to verify the above two conditions. The neural events which are crucial to sustain our life such as those controlling respiration, for example, might be required to be inhibited transiently and safely to test whether those neural events are included in the msckNCC. Although several interesting techniques including combination of optogenetics and modern methodologies in system neuroscience (Kim et al., 2017) have been developed to manipulate neural activities in non-human animals, their spatiotemporal precision appears to be still not enough to perform experiments demanded here and required to be far more improved. However, this argument points just a technical difficulty and, in principle, a technical difficulty is likely to be overcome in the future.

Some may argue that the requirement of the existence of an msckNCC to establish CHANCE leads to a circular argument: establishment of CHANCE may enable the knowledge a cC itself to be directly available in science leading to clarify its neural bases, but in order to establish CHANCE we first need to know what these bases are. This potential argument comes from no distinction between the degree of epistemic objectivity of the knowledge of the cC before and after the establishment of CHANCE. Before the establishment of CHANCE, the knowledge of a cC itself is epistemically subjective (Figure 2a), while this can become epistemically objective after the establishment of CHANCE (Figure 2d). Thus, the establishment of CHANCE enables the direct study of the knowledge of a cC itself in epistemically objective manner (scientific manner) (Figure 2d), while, during the process to establish CHANCE, the knowledge of a cC is studied in epistemically subjective manner (non-scientific manner) (Figures 2a,b). In other words, epistemically subjective knowledge of neural mechanism of the knowledge of a cC is used to establish CHANCE (Figures 2a,b), and if once CHANCE was established, we could conclude that the ontologically and epistemically subjective knowledge could be changed to epistemically objective, scientific one (Figures 1b, 2d). Thus, once CHANCE was established, ontologically subjective knowledge about neural mechanisms of the knowledge of a cC could be regarded as epistemically objective knowledge and thus scientific data (Figure 2d).

Second step: selecting an msckNCC that produces the knowledge of only one specific cC but not others

Every msckNCC found in the above first step might not necessarily produce the knowledge of only one specific cC but multiple cCs. Second step is to select an msckNCC that produces the knowledge of only one specific cC but not others (Figure 2b). This second step would be verified, if the researcher/subject whose brain was manipulated continued to experience and know a specific cC when a specific msckNCC occurred, even if any other neurons or, more generally, neural mechanisms in his/her brain were activated or inhibited. In other words, the manipulated researcher/subject should experience and know a specific cC when a specific msckNCC occurrs, regardless of the occurrence of *any other neural events*. If once an appropriate msckNCC was determined and selected, an occurrence of a specific msckNCC would be indicative of the production of the knowledge of a specific cC.

One may argue that it is implausible to verify this second step because we know that a cC is highly sensitive to context: for example, the brightness of two patches, where their absolute luminance is identical, is experienced and known very differently when they are surrounded by different contexts. However, this case doesn't necessarily mean that a specific msckNCC produces the knowledge of two different cCs, depending on other neural activities. Instead, this case is interpreted as follows: experience and knowledge of brightness of patch A surrounded by context A is produced by a specific msckNCC, while experience and knowledge of brightness of patch A surrounded by different context B is produced by a different msckNCC. That is, different experiences and knowledge of brightness of the identical patches in absolute luminance surrounded by different contexts are produced by the different msckNCCs. Specific stimulus information (e.g., luminance of patch) induces a specific msckNCC in a specific situation but induces another msckNCC in a different situation, depending on other information such as that of surrounding context.

Third step: among the msckNCCs that verified the second step, selecting an msckNCC that is reproducible in multiple brains

Every msckNCC might not necessarily simple enough to be reproduced in multiple brains. Third step is to select, among the msckNCCs that verified the above second step, an msckNCC that is reproducible in multiple brains (Figure 2c). In order to test whether a specific msckNCC can be reproduced in multiple brains, we firstly need to develop sophisticated technologies to reproduce a specific neural event of focus in multiple brains. For example, if the essential neural events of the msckNCC were the specific activity patterns in specific neural networks, such as activity in the Global Neuronal Workspace (GNW) (Baars, 1989; Dehaene et al., 1998; Dehaene and Changeux, 2011), the same patterns of activation should be reproduced in multiple brains. The msckNCCs reproduced in multiple brains should be identical. To be sure that the reproduced msckNCCs are indeed identical, prior precise identification of the neural events of the msckNCC, e.g., specific neural or synaptic activity pattern, in the above first step 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 reproduce some neural events in multiple brains, but present precision appears to be still not enough to reproduce potential neural events of the msckNCC, such as the activity in the GNW, in multiple brains.

The knowledge of a specific cC would be regarded as epistemically objective if the above three steps were verified

If the above three steps were verified, an occurrence of a specific msckNCC (first step) (Figure 2a) would produce the knowledge of a specific cC regardless of background activity of any other mechanisms (second step) (Figure 2b), and a specific msckNCC would be reproduced in multiple brains (third step) (Figure 2c). Given the Leibniz's Law, "the law that for anything *x* and for anything *y*, if *x* is identical with *y* then *x* and *y* share *all* the same properties" (Tye M, 2018), the reproduced msckNCCs, which are identical in multiple brains (third step), should share *all* the same properties including a property to produce the knowledge of a specific cC (second step) (Figure 2d). Thus, the reproduced identical msckNCCs in multiple brains should produce the knowledge of identical cCs in multiple individuals (Figure 2d). Finally, multiple relevant individuals who can judge the faithfulness of the shared knowledge of the identical cC join the experiment. Now, the knowledge of the identical cC which is shared in the multiple relevant individuals and subjectively judged as the truth (being truly had) in the ontological sense in each individual would be regarded as epistemically objective (Figures 1b, 2d). Consistent with this conclusion, Velmans argued that shared experiences among multiple individuals might 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).

One may argue that it's not clear how we can be sure that the knowledge of a cC in multiple individuals is not different from each other by the influence of surrounding neural activities which are not reproduced among them. This argument appears to come from misunderstanding of the above second step. The second step selects a specific msckNCC that produces the knowledge of only one specific cC regardless of the activities of any other neural mechanisms (Figure 2b). Even if neural events which were not reproduced among the individuals were different among the individuals, they would not influence the specific-msckNCC-induced knowledge of the cC, because the knowledge of a specific cC can be completely produced by a solely specific msckNCC under any activities of other neural events (second step) (Figure 2b).

Some may argue that we need to demonstrate that knowledge of the cC shared in multiple individuals is indeed identical among multiple individuals. As mentioned above, identicalness of the cCs experienced and known by each individual is a logical consequence of the above second and third steps and Leibniz's Law: a specific msckNCC produces the knowledge of a specific cC regardless of any other neural activities (second step), the identical msckNCC is reproduced in multiple individuals (third step), and, thus, the identical msckNCCs should produce the knowledge of an identical cCs (logic of Leibniz's Law). Therefore, identicalness of knowledge of shared cC among multiple individuals is guaranteed by logic without direct empirical demonstration of it.

Someone may argue that, in an *Inverted Spectrum* scenario (Block, 1980; 1990; Shoemaker, 1982), an msckNCC generating the knowledge of a red content in one subject, for example, could be identical to an msckNCC producing the knowledge of a green content in another. This argument appears to originate from misunderstanding of the second step and Leibniz's Law. If a specific msckNCC produced the knowledge of a specific cC regardless of any other activities (second step), the identical msckNCCs reproduced in multiple brains should produce the knowledge of an identical cCs (logic of Leibniz's Law). Therefore, if msckNCCs reproduced in two subjects were identical, and if an msckNCC in one subject produced the knowledge of a red content, another identical msckNCC in another subject should produce the knowledge of a red content but not a green one.

Discussion

The degree of epistemic objectivity of a specific entity appears to be reasonably judged by relevant individuals

We argue that the number of relevant individuals who judge a specific entity as the truth appears to affect the degree of epistemic objectivity of the entity (Figure 1b). One factor at least that appears to facilitate judgment of a specific entity as the truth is the reproducibility of the entity: an experimental result, for example, which is reproducibly obtained in further experiments is regarded as faithful to the truth and epistemically objective, while the one not reproducible anymore appears to be regarded as an artifact and not objective. A specific apple on the table, for example, which continue to exist for several weeks, in other words, exist reproducibly, is judged as the truth (truly existing) and epistemically objective. This reproducibility of the existence appears to increase faithfulness of the entity to the truth and thus facilitate judgment of the entity as the truth. Note that the knowledge of an identical and shared cC (Figure 2d) would be reproducible, since the underlying msckNCC was reproducible (third step) and the identical msckNCC necessarily produced the knowledge of the identical cC (second step and Leibniz's Law), supporting the idea that the knowledge of the identical cC which is shared in the multiple relevant individuals would be subjectively judged as the truth (being truly had) in the ontological sense in each individual and thus regarded as epistemically objective (Figures 1b, 2d).

The degree of the epistemic objectivity of an entity appears to have been reasonably judged by relevant individuals (Reiss and Sprenger, 2017). It remains unclear, however, which community members or individuals would judge the degree of epistemic objectivity of the shared knowledge of the identical cC (Figure 2d) if CHANCE was established. In addition, it is also unclear how many relevant individuals who judge the knowledge of the cC as the truth are needed and what degree of epistemic objectivity is needed for the knowledge of the cC to be regarded as a target of science. We argue that it is important to develop a standard for quantification of the degree of epistemic objectivity of a specifc entity and a consensus about what degree of epistemic objectivity of the entity is needed to be a target of science.

Nagel's question would be answered, and both 'Inverted Spectrum' and 'Philosophical Zombie' would be denied

If CHANCE was established and the knowledge of an identical cC was shared among multiple individuals (Figure 2d), 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 (researcher) should somehow share the cC of a subject (participant) (Baars, 1996), which would be realized if CHANCE was established (Figure 2d). If CHANCE was established, the observer (researcher) would share the knowledge of identical cC with the subject (participant) and thus have "observer empathy" (Baars, 1996) and know what it is like to be the subject. In addition, in the situation, we would be able to deny the possibility that the observer (researcher) and the subject (participant) experienced and knew *Inverted Spectrum* (Block, 1980; 1990; Shoemaker, 1982) since they would share knowledge of identical cC. We would also be able to deny another possibility that the subject (participant) was *Philosophical Zombie* (Chalmers, 1996) since the subject (participant) would experience and know identical cC experienced and known by the observer (researcher). Taken together, if once CHANCE was established, we would experience and know what it is like to be others (Nagel, 1974) and be sure that others do not experience and know *Inverted Spectrum* (Block, 1980; 1990; Shoemaker, 1982) and that others are not *Philosophical Zombie* (Chalmers, 1996).

Some obstacles in first-person data would 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 cC (Chalmers, 2013). It has been claimed, however, that first-person data is accompanied with some obstacles, including *Privacy*, *Methods,* and *Formalisms* (Chalmers, 2013) when the data are 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" (Chalmers, 2013) and only indirectly available to others (Figures 1a, 3a). However, if the knowledge of a specific cC of one person was shared among others (Figure 2d), first-person data concerning the cC would be *directly* available to others, so those data would not be private at all (Figure 3b). *Methods* claim that current "methods for gathering first-person data are quite primitive" (Chalmers, 2013). If the knowledge of a specific cC of one person was shared among others, it would not be required to gather first-person data since it would be *directly* available to others (Figures 1b, 3b). *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, if the knowledge of a specific cC of one person was shared among others, gathering of first-person data would not be required, so formalism for this would not be required as well. On the other hand, the development of formalism might be required to write down any results of experiments and to construct and describe a theory explaining relationship between the knowledge of the cC and underlying neural mechanisms. Therefore, epistemic objectification of the knowledge of the cC itself would overcome several, if not all, obstacles involved in first-person data (Chalmers, 2013) and open a new way to incorporate first-person data in science of consciousness.

Epistemic objectification of the knowledge of the cC itself would enable researchers to know the full spectrum of the subjects' cC in scientific experiments.

How our scientific studies of the cC would be changed if the knowledge of the cC itself was changed from epistemically subjective to objective? In a former, typical experimental setting, researchers *indirectly* examine the subjects' cC through the subjects' behavioral reports, bodily signs, or neural signals. None of these readouts of the cC, however, has contained enough information to know the full spectrum of the subjects' cC. This methodological limitation often makes it difficult to examine the subjects' cC reliably. In addition, the methodological limitation makes it difficult to focus on the cC which is beyond words, such as a feeling of love, and this limited availability of a cC makes it difficult to find a general principle, if any, of the neural bases of a huge variety of cCs through inductive reasoning, one of major scientific methods to go from the specific to the general.

If the knowledge of the cC itself was changed from epistemically subjective to objective, the knowledge of the identical cC, which is shared among researchers/subjects (participants), would be able to be *directly* examined by the researchers/subjects (participants) themselves through their own subjective knowledge in the ontological sense (Figure 3b). Here, the shared knowledge of the cC would be ontologically subjective, identical among participants, and epistemically objective. Thus, the ontologically subjective knowledge of the cC itself of each researcher/subject (participant) would be epistemically objective and available as scientific data (Searle, 1998). In principle, a cC which is beyond words would have a potential to be a target of scientific investigation. A person or researcher who wants to know the data, he/she would have to join the experiment and experience and know the shared knowledge of a cC by himself/herself, proposing a novel scientific method to investigate the knowledge of a cC and its neural bases.

Limitations of CHANCE

The msckNCC is defined as a neural event which is minimally sufficient to produce *the knowledge of* a specific cC *without any other supportive mechanisms* (Figure 2a). The knowledge of a specific cC means information of the cC experienced by somebody. Having knowledge of a specific cC means both experiencing the cC and sensing of an observing self. Thus, the msckNCC, which produces the knowledge of a specific cC, should include not only a neural event which is sufficient to produce the cC itself but also a neural event which is sufficient to produce the sense of an observing self, in other words, subjectivity (Baars, 1996). Therefore, CHANCE would not be able to specifically identify a neural event which is minimally sufficient to produce a specific cC itself and *can not separate consciousness from function* (Cohen and Dennett, 2011).

Conclusion

In scientific experiments, a consciousness researcher has examined the cC of a subject (participant) *indirectly* through the subject's behavioral reports, bodily signs, or neural signals. With these methods, it has been quite difficult for a researcher to know the full spectrum of the subject's cC. We propose CHANCE that enables a researcher to know *directly* the full spectrum of the subject's cC. In addition, CHANCE enables the researcher's ontologically subjective knowledge about the subject's cC to be regarded as scientific data. Thus, a researcher would *directly* deal with the full spectrum of the cC in science. We believe that CHANCE would pave the way to investigate the neural bases of the full spectrum of the cC and contribute to solve the *hard problem* of consciousness (Chalmers, 1996).

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References

Baars BJ (1989) A Cognitive Theory of Consciousness. Cambridge, Mass: Cambridge University Press.

Baars BJ (1996) Understanding subjectivety: Global workspace theory and the resurrection of the observing self. Journal of Conscious Studies 3:211-216.

Block N (1980) Are absent qualia impossible? Phylosophical Review 89:257-274.

Block N (1990) Inverted Earth. Philosophical Perspectives 4:53-79.

Chalmers DJ (1995) Facing up to the problem of consciousness. Journal of Consciousness Studies 2:200-219.

Chalmers DJ (1996) The conscious mind: in search of a fundamental theory. New York, NY: Oxford University Press.

Chalmers DJ (1999) First-person methods in teh science of consciousness. Consciousness Bulletin.

Chalmers DJ (2000) What is a neural correlate of consciousness? Cambridge, MA: MIT Press 17-39.

Chalmers DJ (2013) How can we construct a science of consciousness? Ann N Y Acad Sci 1303:25-35.

Click F, Koch C (1990) Toward a neurobiological theory of consciousness. Seminars in the Neuroscience 2:263-275.

Cohen MA, Dennett DC (2011) Consciousness cannot be separated from function. Trends Cogn Sci 15:358-364.

Craig AD (2009) How do you feel--now? The anterior insula and human awareness. Nat Rev Neurosci 10:59-70.

Dehaene S, Changeux JP (2011) Experimental and theoretical approaches to conscious processing. Neuron 70:200-227.

Dehaene S, Kerszberg M, Changeux JP (1998) A neuronal model of a global workspace in effortful cognitive tasks. Proc Natl Acad Sci U S A 95:14529-14534.

Del Cul A, Baillet S, Dehaene S (2007) Brain dynamics underlying the nonlinear threshold for access to consciousness. PLoS Biol 5:e260.

Dennett DC (1991) Consciousness Explained. Little Brown.

Dennett DC (2001) The fantasy of first-person science. https://asetuftsedu/cogstud/dennett/papers/chalmersdeb3dfthtm.

Descartes R (1644) Treatise on Man, trans. T.S.Hall. Harvard University Press, 1972.

Frassle S, Sommer J, Jansen A, Naber M, Einhauser W (2014) Binocular rivalry: frontal activity relates to introspection and action but not to perception. J Neurosci 34:1738-1747.
Freeman WJ (2007) Indirect biological measures of consciousness from field studies of brains as dynamical systems. Neural Netw 20:1021-1031.
Galileo G (1623) The Assayer. In The Controversy on the Comets of 1618. Translated by
Stillman Drake. Philadelphia: University of Pennsylvania Press, 1960.
Garcia JO, Srinivasan R, Serences JT (2013) Near-real-time feature-selective modulations in human cortex. Curr Biol 23:515-522.
Haynes JD (2009) Decoding visual consciousness from human brain signals. Trends Cogn Sci 13:194-202.
Horikawa T, Tamaki M, Miyawaki Y, Kamitani Y (2013) Neural decoding of visual imagery during sleep. Science 340:639-642.
James W (1985) Varieties of Religious Experience. New York: Macmillan.
Kim CK, Adhikari A, Deisseroth K (2017) Integration of optogenetics with complementary methodologies in systems neuroscience. Nat Rev Neurosci 18:222-235.
Koch C (2004) The quest for consciousness: a neurobiological approach. Englewood, CO: Roberts and Co.
Koch C, Massimini M, Boly M, Tononi G (2016) Neural correlates of consciousness: progress and problems. Nat Rev Neurosci 17:307-321.
Koch C, Tsuchiya N (2007) Attention and consciousness: two distinct brain processes. Trends Cogn Sci 11:16-22.
Kok P, Rahnev D, Jehee JF, Lau HC, de Lange FP (2012) Attention reverses the effect of prediction in silencing sensory signals. Cereb Cortex 22:2197-2206.
Kunimoto C, Miller J, Pashler H (2001) Confidence and accuracy of near-threshold discrimination responses. Conscious Cogn 10:294-340.
Lamme VA (2003) Why visual attention and awareness are different. Trends Cogn Sci 7:12-18.
Lau H, Rosenthal D (2011) Empirical support for higher-order theories of conscious awareness. Trends Cogn Sci 15:365-373.
Lee W, Kim S, Kim B, Lee C, Chung YA, Kim L, Yoo SS (2017) Non-invasive transmission of sensorimotor information in humans using an EEG/focused ultrasound brain-to-brain interface. PLoS One 12:e0178476.
Lutz A, Lachaux JP, Martinerie J, Varela FJ (2002) Guiding the study of brain dynamics by using first-person data: synchrony patterns correlate with ongoing conscious states during a simple visual task. Proc Natl Acad Sci U S A 99:1586-1591.
Mashat MEM, Li G, Zhang D (2017) Human-to-human closed-loop control based on brain-to-brain interface and muscle-to-muscle interface. Sci Rep 7:11001.
Melloni L, Schwiedrzik CM, Muller N, Rodriguez E, Singer W (2011) Expectations change the signatures and timing of electrophysiological correlates of perceptual awareness. J Neurosci 31:1386-1396.
Nagel T (1974) What is it like to be a bat? The Phylosophical Review 4:435-450.
Nishimoto S, Vu AT, Naselaris T, Benjamini Y, Yu B, Gallant JL (2011) Reconstructing visual experiences from brain activity evoked by natural movies. Curr Biol 21:1641-1646.
Peirce CS (1866/1982) "Lowell Lecture" (ix). Bloomington, Indiana: Indiana University Press.
Ramachandran VS, Hirstein W (1997) Three laws of qualia; What neurology tells us about the biological functions of consciousness. J Conscious Studies 4:429-457.
Reiss J, Sprenger J (2017) "Scientific Objectivity". The Stanford Encyclopedia of Philosophy (Winter 2017 Edition), Edward N Zalta (ed).
Ress D, Backus BT, Heeger DJ (2000) Activity in primary visual cortex predicts performance in a visual detection task. Nat Neurosci 3:940-945.
Sandberg K, Timmermans B, Overgaard M, Cleeremans A (2010) Measuring consciousness: is one measure better than the other? Conscious Cogn 19:1069-1078.
Searle JR (1998) How to study consciousness scientifically. Brain Res Brain Res Rev 26:379-387.
Shoemaker S (1982) The Inverted Spectrum. J Philosophy 79:357-381.
Soto D, Silvanto J (2014) Reappraising the relationship between working memory and conscious awareness. Trends Cogn Sci 18:520-525.

Steup M (2018) "Epistemology". The Stanford Encyclopedia of Philosophy (Summer 2018 Edition), Edward N Zalta (ed).

Super H, Spekreijse H, Lamme VA (2001) Two distinct modes of sensory processing observed in monkey primary visual cortex (V1). Nat Neurosci 4:304-310.

Tong F, Meng M, Blake R (2006) Neural bases of binocular rivalry. Trends Cogn Sci 10:502-511.

Tononi G, Koch C (2015) Consciousness: here, there and everywhere? Philos Trans R Soc Lond B Biol Sci 370.

Tsuchiya N, Wilke M, Frassle S, Lamme VAF (2015) No-Report Paradigms: Extracting the True Neural Correlates of Consciousness. Trends Cogn Sci 19:757-770.

Tye M (2018) "Qualia". The Stanford Encyclopedia of Philosophy (Summer 2018 Edition), Edward N Zalta (ed).

Vaerla FJ (1996) Neurophenomenology: A Methodological Remedy for the Hard Problem. J Conscious Studies 3:330-349.

Velmans M (1999) Intersubjective science. Journal of Conscious Studies 6:299-306.

Velmans M (2007) Heterophenomenology versus critical phenomenology. Phenomenology and the Cognitive Sciences 6:221-230.

Yoo SS, Kim H, Filandrianos E, Taghados SJ, Park S (2013) Non-invasive brain-to-brain interface (BBI): establishing functional links between two brains. PLoS One 8:e60410.

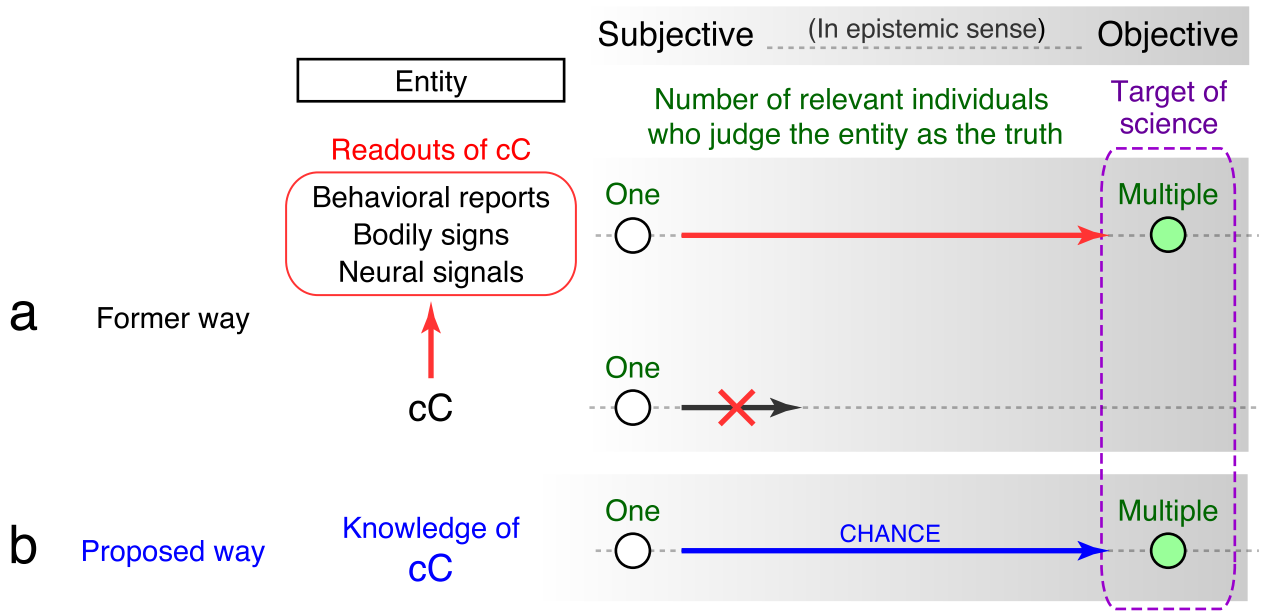

Figure 1. The knowledge of the cC itself can become epistemically objective in a specific condition.
(a) A former, conventional way to deal with the cC in science. More number of relevant individuals who judge the entity as the truth (green characters) contributes to the more objectivity of the entity epistemically. The cC itself is judged as the truth (being truly had) by only the subject oneself and is not possible to be objectified epistemically (red cross). Behavioral reports, bodily signs, or neural signals are used as "readouts" of the cC (left red arrow), and the data of the readouts are recorded by instruments in typical experimental settings, enabling them to be available for multiple individuals (right red arrow). Thus, the cC is indirectly available and examined in science through measuring its readouts (purple dotted line). The problem is that any readout does not fully reflect the cC.
(b) A proposed way to deal with the cC in science. The knowledge of the cC itself is changed from epistemically subjective to objective. If the knowledge of the cC itself was judged as the truth (being truly had) by multiple relevant individuals, it would be regarded as epistemically objective (blue arrow) and thus directly available in science (purple dotted line). CHANCE is a potential method we propose to change the knowledge of a cC from epistemically subjective to objective.
cC: content of consciousness. CHANCE: changing consciousness epistemically.

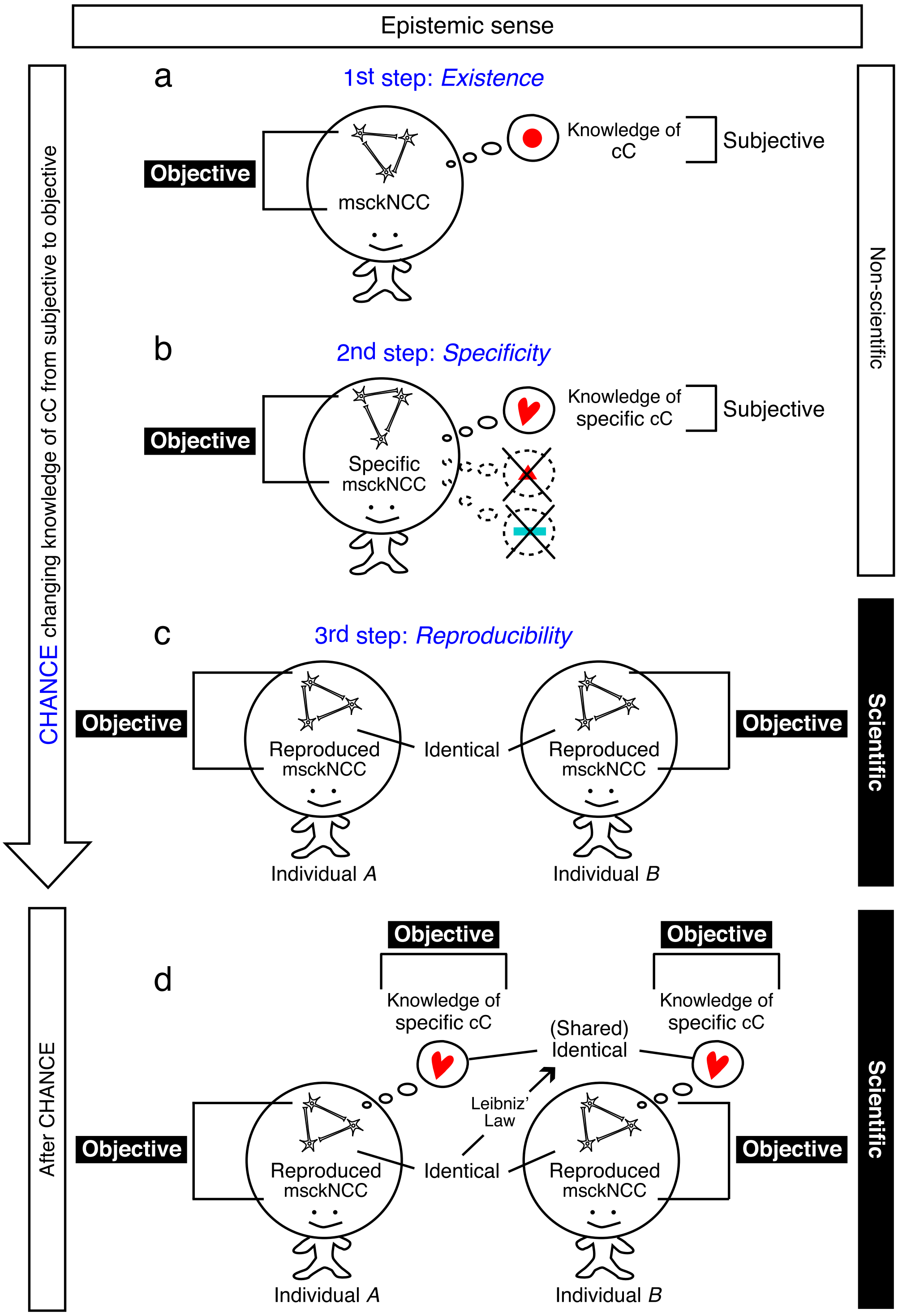

Figure 2. Three steps of CHANCE to change the knowledge of the cC itself from epistemically subjective to objective.
(**a**) First step of CHANCE: finding an msckNCC defined as a minimum neural event that is sufficient (but not necessarily required) to produce the knowledge of a cC (red filled circle). While an msckNCC itself is epistemically objective, the knowledge of a cC is epistemically subjective, making experiments and obtained results in this step non-scientific. This step verifies the existence of an msckNCC.
(**b**) Second step of CHANCE: selecting an msckNCC that produces the knowledge of one specific cC but not others. An occurrence of a specific msckNCC produces the knowledge of a specific cC (red heart symbol) but not others (red triangle and blue rectangle), regardless of an occurrence of any other neural events. As with first step (a), the knowledge of a cC is epistemically subjective, making experiments and obtained results in this step non-scientific. This step verifies the specificity of an msckNCC.
(**c**) Third step of CHANCE: from the msckNCCs that verified the second step (b), selecting an msckNCC that is reproducible in multiple brains. The reproduced msckNCCs among multiple brains are identical. This step contains only epistemically objective entity, the msckNCC. Thus experiments and obtained results in this step are scientific. This step verifies the reproducibility of an msckNCC.
(**d**) A logical consequence of the verification of all the three steps of CHANCE (a-b). An msckNCC which produces the knowledge of a specific cC (red heart symbol) in Indidividial A is identical with an msckNCC of Individual B. An occurrence of the msckNCC in Individual B should produce the knowledge of an identical cC (red heart symbol) with that in Individual A as a logical consequence of the 2nd step (b), 3rd step (c) and Leibniz' Law. In other words, the knowledge of the identical cC (red heart symbol) is shared between Individual A and B by the occurrence of the identical msckNCCs. The knowledge of the identical cC would be subjectively judged as the truth (being truly had) in the ontological sense by multiple individuals (Individual A and B). If multiple relevant individuals who can judge the objectivity of the knowledge of the cC joined the experiment once as subjects (participants), the shared knowledge of the identical cC (red heart symbol) would be regarded as epistemically objective. Therefore, once CHANCE was established, ontologically subjective knowledge about cC and its neural basis would be regarded as epistemically objective knowledge and thus scientific data.
msckNCC, minimally-sufficient content-knowledge-specific neural correlates of consciousness.

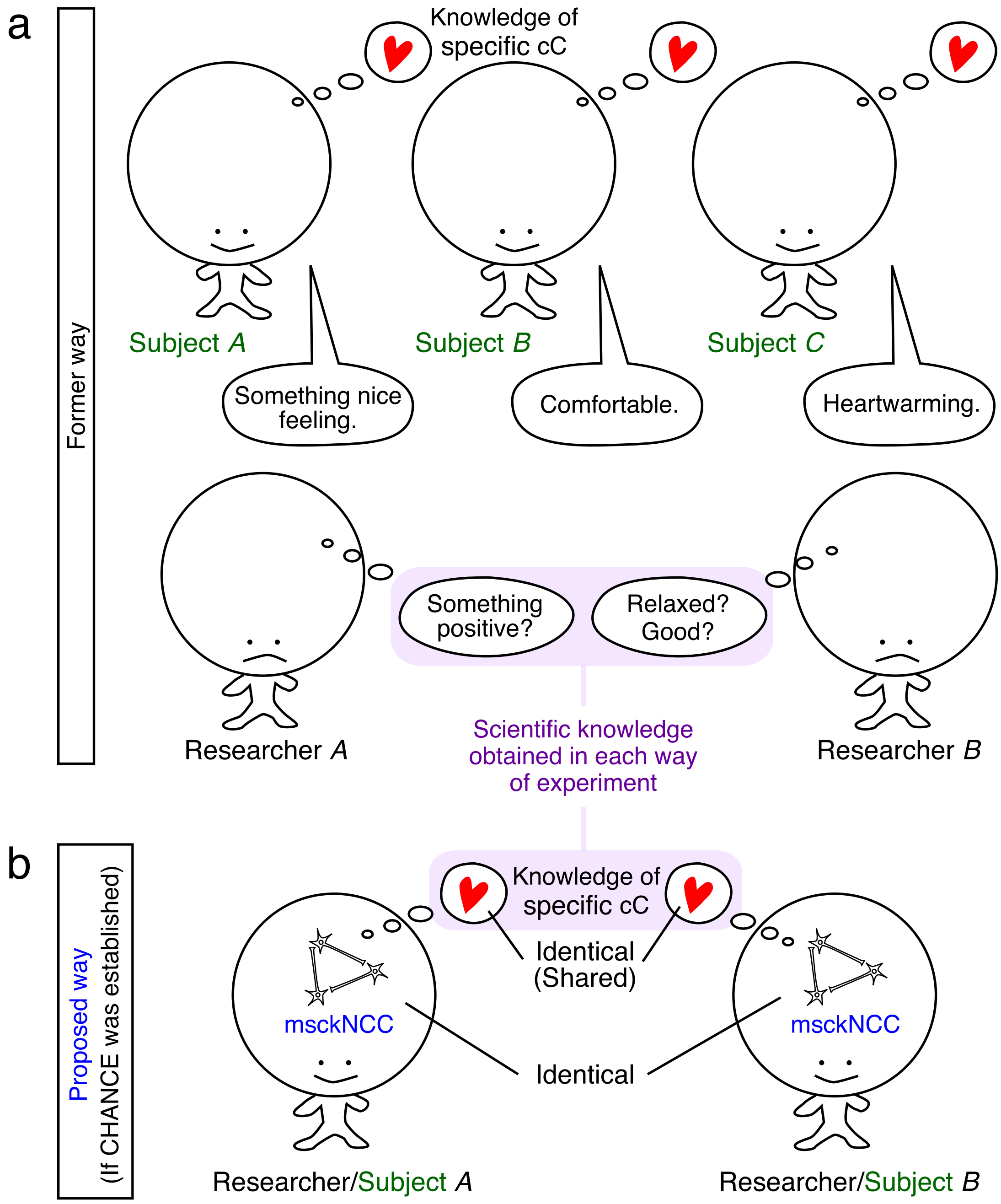

Figure 3. A researcher would experience and know the full spectrum of the subject' s cC in scientific experiments, if once CHANCE was established.

(**a**) A former, conventional way of science of the cC. In most experimental settings, researchers indirectly examine the cC of the subjects (participants) (red heart symbols) through the subjects' behavioral reports including verbal reports. It has been quite difficult to know the full spectrum of the subjects' cC.

(**b**) A proposed way of science of the cC which would be available if once CHANCE was established. Firstly, identical msckNCCs are set in researchers/subjects (participants). This process is technically challenging but possible in principle. The knowledge of the cC produced by the identical msckNCC in each participant is identical and shared among participants and epistemically objective. The ontologically subjective knowledge of the cC itself of each participant would be available as scientific data. A person or researcher who wants to know the data, he/she would have to join the experiment and experience and know the shared cC by himself/herself.