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Knowledge-How and Perceptual Learning

Berit Brogaard
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Abstract

Epistemologists have been divided into two camps with respect to the analysis of knowledge-how. According to intellectualists, knowledge-how is not essentially ability-involving, but requires implicit or explicit beliefs about a procedure that can lead to a desired outcome. According to anti-intellectualists, knowledge-how is essentially ability-involving and need not involve implicit or explicit beliefs about any procedures. Here I argue that both views have currency but with respect to different types of knowledge-how. Intellectualism is best suited as an account of knowledge-how that results from being able to consciously access information about a particular procedure that can lead to a desired end result, for instance, knowing how to make Chana Masala by following a recipe, knowing how to make Google the default search engine in Safari and knowing how to get from Coral Gables to Miami Beach by using a map. Anti-intellectualism, on the other hand, is best suited as an account of knowledge-how that is grounded in expertise acquired through perceptual or proprioceptive learning. Examples of the latter include knowing how to use a ski lift, knowing how to play chess at an expert level and knowing how to determine the sex of a day-old chick.

Keywords: anti-intellectualism; intellectualism; knowledge-how; perceptual learning; personal-level explanation; practical abilities; procedural knowledge; proprioceptive learning; practical and intellectual skill

1. Introduction

Following Gilbert Ryle, it has been common in the contemporary literature on knowledge-how to distinguish between intellectualism and anti-intellectualism. According to the reductionist varieties of intellectualism defended by Jason Stanley and Timothy Williamson (2001) and Berit Brogaard (2007, 2008, 2009), knowledge-how simply reduces to knowledge-that. To a first approximation, *s* knows how to *A* iff there is a *w* such that *s* knows that *w* is a way to *A*. For example, Bartek knows how to ride a bicycle if and only if there is a way *w* such that Bartek knows that *w* is a way to ride a bicycle. John Bengson and Marc Moffett (2007) defend an anti-reductionist version of intellectualism which takes knowledge-how to require, in addition, that *s* understand the concepts involved in her belief.

According to the anti-intellectualist accounts originally defended by Gilbert Ryle (1946) and many others after him (see e.g. Carter & Pritchard 2015a), knowledge how to do something requires the possession of a practical ability the exercise of which will bring about the desired end result and need not involve knowing that a particular procedure is a way to reach the outcome. For example, Bartek knows how to ride a bicycle only if he has the ability to ride it. Furthermore, on the anti-intellectualist view, having this knowledge does not require that Bartek knows that *w* (for some *w*) is a way to ride a bicycle.

Here I start out by arguing that the standard way of differentiating intellectualism and anti-intellectualism rests on a mistake. It is not the possession of practical abilities that sets the two views apart. Nor is it their take on the issue of whether knowledge-how simply reduces to knowledge-that. Rather, the two positions are better seen as providing different answers to the question of whether knowledge-how requires implicit or explicit (personal-level) beliefs about a particular procedure that can lead to the desired outcome. Intellectualism is best understood as the view that knowledge-how *does* require a personal-level mental state about a particular procedure, whereas anti-intellectualism is best understood as the view that it does not.

After articulating this alternative distinction between intellectualism and anti-intellectualism, I will argue that both views have currency but with respect to different types of knowledge-how. Some types of knowledge-how require having the ability to consciously access information about a procedure that will achieve a desired goal, for instance, knowing how to make Chana Masala by following a recipe, knowing how to make Google the default search engine in Safari and knowing how to get from Coral Gables to Miami Beach by using a map. Another type of knowledge-how to do something does not require this type of conscious accessibility but is instead the result of expertise acquired through perceptual or proprioceptive learning. Examples of the latter include knowing how to ride a bicycle, knowing how to speak Spanish, knowing how to play chess at an expert level and knowing how to determine the sex of a day-old chick.

2. Belief-Based Knowledge-How

There is a marginal use of ‘know-how’ which I will briefly mention only to set it aside. We might say about a former Olympic gymnast who is no longer performing but who is now teaching her own students that she knows how to perform a quadruple salchow, even if she can no longer do it herself. Likewise we might say of someone who is bedridden but who has a good sense of direction that he knows how to complete a run from Brickell Key to South Beach, even though he cannot do it himself. These sorts of cases are not the main instances of knowledge-how at the center of dispute between intellectualists and anti-intellectualists. In fact, one could sensitively maintain that without the relevant practical abilities, the individuals in question do not possess knowledge of how to perform the relevant activities.

There are other kinds of knowledge-how that are not at the center of dispute between intellectualists and anti-intellectualists. These are instances of knowledge-how none of which require practical abilities to do anything but refer to a fact that the subject knows without mentioning what the fact is, for instance, the knowledge referred to by claims such as ‘Bartek

knows how hot it is', 'Sebastian knows how old Anna is' and 'Michael knows how far Miami is from Orlando'. When we make these kinds of claims, we are not aiming to pick out instances of *knowledge how to do things*. Rather, we are making claims that are semantically on a par with statements such as 'Sarah Beth knows where the meeting is', 'Peter knows what Alex had for lunch' and 'Lisa knows who stole the Macbook Air'. Sarah Beth knows where the meeting is just in case there is a location such that Sarah Beth knows that the meeting is at that location. Likewise, Sebastian knows how old Anna is just in case there is an age such that Sebastian knows that Anna is that age. I shall not be concerned with this other type of knowledge-how here but shall focus exclusively on knowledge of how to do things.

We are left then with a type of knowledge-how that does indeed require the possession of practical abilities.[1] This may suggest that anti-intellectualism is correct and that intellectualism is not. This conclusion, however, is premature. Although the distinction between intellectualism and anti-intellectualism is typically articulated in terms of whether knowledge-how just is a form of knowledge-that and hence appears to depend on whether the knowledge state in question requires the possession of practical abilities or not, this is not in fact what distinguishes the two views. Stanley and Williamson (2001), for instance, hold that knowledge-how typically requires knowing that there is a way *w* such that *w* will lead to the desired end result under a certain practical mode that requires the possession of the relevant practical abilities. So, if the focus is on whether knowledge-how requires the possession of practical abilities, then there is no real dispute between intellectualism and anti-intellectualism (Levy, forthcoming).

A more fruitful way to draw the distinction between intellectualism and anti-intellectualism is in terms of whether knowledge of how to do things requires belief-based knowledge. Intellectualism is best understood as the view that it does, whereas anti-intellectualism is best understood as the view that it does not.

Here 'belief' should not be understood as referring only to the explicit belief that for some procedure *w*, *w* is a way to do *A*. For the reductive intellectualist, a dispositional or implicit (true) belief that a certain procedure will lead to *A*, together with a justificatory ground for the belief and the relevant practical abilities, suffices for knowing how to do *A*. Note, however, that in order for a mental state to count as a belief (whether dispositional, implicit or explicit), the subject must be able to consciously access it. If a mental state or dispositional structure is inaccessible to consciousness, then it subsists only on a sub-personal level and hence does not count as a belief.

Following Daniel Dennett (1969:93), the distinction between the personal level and sub-personal level is grounded in distinct kinds of explanations one can provide for why people behave the way they do. The distinction is that between 'the explanatory level of people and their sensations and activities and the sub-personal level of brains and events in the nervous system' (1969: 93). Personal level explanations are distinctive kinds of explanation for persons:

> When we've said that a person's in pain, that she knows which bit of her hurts and that this is what's made her react in a certain way, we've said all that there is to say within the scope of the personal vocabulary.... If we look for alternative

[1] Following the literature in psychology, we can also refer to this as 'procedural knowledge' (Stadler, 1989). Some limit the notion of procedural knowledge to the second type of knowledge-how, which I will deal with in the next section.

> modes of explanation, we must abandon the explanatory level of people and their sensations and activities and turn to the sub-personal level of brains and events in the nervous system (1969: 93).

Although personal-level explanations may refer to a-rational mental states, like pain, they can also refer to mental states that are assessable for rationality, such as 'needs, desires, intentions and beliefs' (Dennett 1969: 164). Subpersonal-level explanations, on the other hand, are not concerned with normative properties such as that of being rational; they merely make reference to causal relations and mechanisms. As belief is a type of state that contributes to making behavior intelligible in terms of norms of rationality, mental states or dispositional structures that are inaccessible to consciousness do not and cannot count as belief states. So, the intellectualist position, as originally stated, is best understood as maintaining that in order for a subject to have knowledge of how to do A, a (personal-level) belief that a particular procedure can lead to *A* is required.

Some types of knowledge-how seem to satisfy this criterion. Consider a culinary novice *s* who is successfully cooking a potful of Chicken Tikka Masala for the first time by following a recipe that he believes will result in a potful of the famous Indian dish. It makes perfect sense to say that *s* knows how to cook Chicken Tikka Masala, even if he is no master chef and has to pay close attention to each step of the recipe in order to reach the desired outcome. In this case, *s* can be said to possess knowledge of how to cook the Indian dish only insofar as he is able to consciously access true information about a particular procedure will lead to the desired end result. Although *s* would not be able to cook the Indian dish without having certain pre-existing practical abilities, such as following the recipe and adding ingredients to the pot, his knowledge of how to cook the dish is not the result of exercising enhanced perceptual or proprioceptive skills specific for the task at hand. A satisfactory explanation of why *s* added onion, tomato paste, cardamom, and chiles to the heated ghee in the pot would not need to cite any new ways that *s* is perceiving the world or is controlling various parts of his body. A personal-level explanation to the effect that *s* wanted to cook a potful of Chicken Tikka Masala and believed that following the steps in the recipe would lead to the desired outcome would be quite good enough.

As another example of a case where the intellectualist has the upper hand, consider Paul Snowdon's example of a man in a room who lacks knowledge of how to get out, despite apparently having the ability to get out:

> A man is in a room, which, because he has not explored it in the least, he does, as yet, not know how to get out of. In fact, there is an obvious exit which he can easily open. He is perfectly able to get out, he can get out, but does not know how to (as yet) (Snowdon 2003: 11).

It seems perfectly alright to say that the man has the ability to get out of the room (he just has to look around) and yet it seems highly plausible that he doesn't know how to get out. He doesn't know how to get out because there presently is no way *w* such that he believes that *w* is a way to get out.

Snowdon uses the example to illustrate that the possession of practical abilities is not sufficient for knowledge-how. However, when Snowdon points out that the man 'is perfectly able to get out', he is using the expression 'ability' loosely. Snowdon is right that the man in question

does not know how to get out but while there is a sense in which he is able to get out (he has the practical ability to complete the steps), there is another sense in which he is unable to the. If asked by his mate whether he is able to get them out, the man would be wise to answer 'no'. 'Ability' can thus be used in two different ways (Brogaard, 2011). In one sense of the word, *s* has the ability to *A* just in case *s* has a true belief that represents a certain procedure that will lead to *A*, and *s* has the bodily capacities needed to carry out the procedure. In another sense, *s* has the ability to *A* just in case *s* has the bodily capacities to carry out a procedure, even though the procedure is unknown to him. The man in Snowdon's example does not have a belief that a particular procedure will allow him to get out; he merely has the bodily capacities. Only the first kind of ability suffices for knowledge-how in the intellectualist sense.

'Ability', of course, is frequently used in the second way in ordinary language. For example, we might say: 'Of course, you can swim, everyone can swim, you just have to learn it first' or 'Of course, she is perfectly able to walk, she just doesn't know how to yet, she is only eleven months old'. Or consider a variation on the man-in-the-room example. To get out one must press a button behind the bookshelves, step on a particular floor plank, and yell 'out' three times. Even so, saying the following seems perfectly fine: 'Of course, the man is perfectly able to get out. He just has to press a button behind the bookshelves, step on a particular floor plank, and yell "out" three times'. However, in neither the original case nor the variation can we attribute to the agent a true belief that a particular procedure will lead to the desired outcome. Hence, the agents in these scenarios do not know how to get out (as yet). They have not yet internalized the relatively simple procedures which will lead to their escape.

Snowdon is thus right for some cases of knowledge-how: there are cases in which pre-existing bodily capacities do not suffice for know-how. In those cases pre-existing bodily capacities must be combined with procedures that have been internalized by the agent on a personal level. But this internalization of a procedure is just another way of referring to the formation of an implicit or explicit belief concerning a procedure that can lead to the desired end result.

In cases like these where the knowledge-how requires internalizing a procedure on a personal level and where the knowledge-how therefore is belief-based, intellectualism seems to offer an adequate description of the acquired knowledge-how. This is not to say that knowledge-how, in these cases, straightforwardly reduces to knowledge-that (plus practical abilities) (see Bengson & Moffett, 2011; Brogaard, 2011; Cath, 2011, 2015; Carter & Pritchard, 2015a, 2015b, 2015c). As I have argued in previous work (Brogaard, 2011), the justificatory ground needed to turn a true belief that carrying out a particular procedure will lead to the desired outcome into knowledge how to reach the desired outcome may simply consist in having the practical abilities required to successfully follow the particular procedure.[2]

[2] Consider the following case (Brogaard, 2011): The faucet in Jason's apartment leaks. Jason finds a faucet manual in the kitchen drawer and fixes it. However, unbeknownst to him, the manual was created by the previous owner's parrot who liked to step dance on the keyboard of the owner's old typewriter. Over the fifty years of step dancing the parrot had created a lot of nonsense but there was this one time where the parrot happened to hit the right keys and created something that made sense: 'the faucet manual'. The owner never looked at it but had left it in the kitchen drawer where Jason found it. Although Jason believes that there is a procedure that, if successfully followed, will lead him to fix the faucet, this belief is acquired via a faulty method. So Jason's knowledge is not based on warranted belief. Even so, it

There are other cases of knowledge-how, however, in which we know how to do things, not as a result of being able to consciously access information about a procedure that will lead to a desired end result but rather as a result of exercising practical abilities acquired through perceptual or proprioceptive learning. I will turn to this type of knowledge-how next.

3. Perceptual and Proprioceptive Learning

Knowledge-how that ensues from perceptual learning does not consist in having conscious access to a belief that a set of steps can lead to a desired outcome. Perceptual learning, unlike other forms of learning, can be defined as 'experience-induced changes in the way perceivers pick up information' (Kellman & Garrigan, 2009) or as extracting perceptual information that was previously unused (Gibson & Gibson, 1955). In the case of perceptual learning, repeated exposure to a particular task makes us more attuned to the relevant features and structural relations that characterize the task in question. The heightened attunement to features and structural relations in perceptual learning can virtually never be articulated by the learner. This suggests that the knowledge-how in question is not accompanied by any belief-like states to the effect that a particular procedure will lead to a desired end result. In fact, the processes that drive the knowledge-how seem best characterized as perceptual processes that occur on a sub-personal level (Dennett, 1969) but that nonetheless can yield a reportable outcome.

Three mechanisms have been identified as responsible for perceptual learning (Goldstone, 1998). One way that knowledge-how is acquired through perceptual learning is through imprinting. Through imprinting, detectors (also known as 'receptors') are developed that are specialized for stimuli or parts of stimuli. The receptive fields of the neurons that initially encode the stimulus adapt to become more sensitive to important features and structural relations. There is evidence for both perceptual learning via whole stimulus storage and perceptual learning via imprinting on specific features within a stimulus. Evidence for the former comes from cases where people's performance in perceptual tasks improves with increased exposure to a particular stimulus. It has been shown, for instance, that people can identify spoken words more accurately when they are spoken by familiar voices (Palmeri et al 1993), and that doctors' diagnoses of skin disorders become more accurate when they are similar to previously presented cases (Brooks, et al., 1991). There is also evidence of imprinting on parts of, or features of, a perceptual stimulus, leading to the generation of new building blocks for recognizing and describing stimuli (Schyns, et al. 1998; Schyns & Murphy, 1994).

A second way that knowledge is acquired through perceptual learning is through a development of the ability to differentiate low-features of a stimulus that once were perceived as fused together. Painters and vision scientists, for instance, have been shown to be better able to

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seems alright to say that Jason knows how to fix the faucet. In this case, the justificatory ground for Jason's belief that following the manual will fix the faucet consists in having the ability to follow the steps in the manual. As I have argued elsewhere (Brogaard, 2011), having the ability to follow the steps in the manual can count as a justificatory ground because the true belief together with the abilities constitute a reliable way of reaching the desired outcome.

selectively attend to features of color, such as hue, brightness and saturation compared to non-experts (Burns & Shepp 1988). Presumably what happens is that the learner learns to increase the attention paid to important perceptual features and decrease attention paid to irrelevant features (Ahissar and Hochstein, 1993). So, while the changes in perceptual abilities that take place in perceptual learning occur at stages of low-level processing in the brain, high-level attentional mechanisms are crucial in controlling these changes at the level of early processing. Perceptual learning effects of this kind thus reflect top-down influences on early vision (or other sensory systems), consisting in learning to attend to relevant stimuli (Saarinen & Levi, 1995).

An oft-discussed example of knowledge-how that results from this latter type of perceptual learning is that of knowing how to determine the sex of chicks. Professional chicken sexers can classify 1,000 chicks per hour at over 98 percent accuracy (Biederman & Shiffrar, 1987). This means that they spend less than a second looking at each chick. Chicken sexers typically cannot articulate how they determine the sex of a chick. There is, indeed, a rough procedure that can be identified as underlying the perceptual abilities of chicken sexers. In typical cases, chicks, only a few hours old, are brought to the sexer in trays of 100. The chicken sexer holds the chick in the left hand and squirts its fecal contents in a container to clear the cloaca. He or she then exerts pressure to spread the surface of the cloaca upwards to expose what is called the ‘bead’. The bead is the size of a pinhead. In typical cases, the male genitals look round and full, whereas the female genitalia either look pointed or flat (**Fig. 1**).

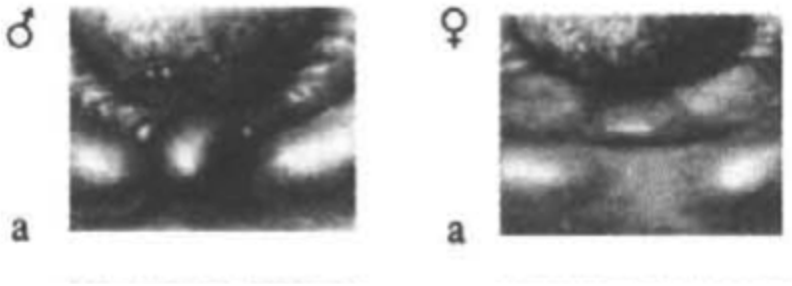

Figure 1: Male chicken genitals tend to look round and full like a ball or watermelon. Female chicken genitals typically take on one of two different appearances. They can look pointy, like an upside down pinetree, or flattish (as in the picture). From Biederman & Shiffrar (1987).

There are, however, lots of exceptions to the typical cases; so chicken sexers implicitly use a number of different rules for determining the sex of chicks. For instance, male chicks sometimes (but not always) have larger genitalia than female chicks. Sometimes additional pressure need to be applied to obtain the critical contour information needed to determine the sex of the chick. This may explain why the success rate of experts who have only pictures to go by drops to 72 percent.

A third way that knowledge-how is acquired through perceptual learning is through unitization, which may seem to be the opposite of differentiation. Whereas differentiation divides wholes into more differentiated features, unitization integrates parts into single units or chunks.

This is typically what happens when people become expert chess players. Whereas novices are only able to encode the position of the individual chess pieces in long-term memory, expert chess players encode chess configurations. The basic unit encoded in long-term memory is the ‘chunk’, which consists of a configuration of pieces that are frequently encountered together and that are related by type, color, role, and position (Chase and Simon, 1973a, 1973b). The number of figurations that the expert player has stored in long-term memory can be as high as 300,000 (Gobet & Simon, 2000). The chunks can also be encoded in a combined form known as ‘templates’ (Gobet & Simon, 1996).

Knowledge-how that is the result of expertise based on perceptual learning is not belief-based. It is grounded in cellular changes to areas of low-level sensory processing in the brain. This has been studied, for instance, in the case of Vernier acuity (Kellman & Garrigan, 2009). In a standard Vernier task, two lines, one above the other, are shown on each trial, and the participant is supposed to determine whether the upper line is to the left or right of the lower line (**Fig. 2**). Vernier acuity is incredibly precise even without training. Some individuals can accurately detect misalignments smaller than 10 arc secs, which is less than the diameter and spacing of retinal cone receptors (Westheimer & McKee, 1978). It is believed that these individuals detect the misalignment by relying on cortical processing (Hennig, et al., 2002). This ability is also known as ‘hyperacuity’ (Westheimer, 1975). Radically enhanced Vernier acuity, and even hyperacuity, can be achieved through perceptual learning trials. 8,000 trials have been shown to lead to up to a six-fold decrease in detection threshold (Saarinen & Levi, 1995; Kellman & Garrigan, 2009).

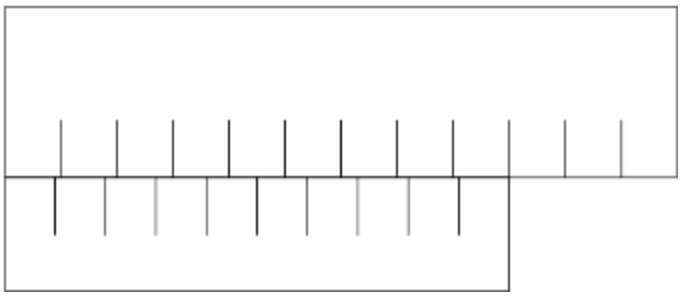

Figure 2. Vernier scale. Vernier acuity measures the ability to discern a misalignment among two line segments or gratings.

In these visual learning tasks, training appears to yield a kind of "fine tuning" at the early stages of visual processing underlying the tasks (Saarinen & Levi, 1995; McKee & Westheimer, 1978). These changes in the neural structure of visual processing likely owes in part to top-down influences on early vision, consisting in learning to attend to relevant stimuli (Saarinen & Levi, 1995).

As these processes are grounded in structural changes in early visual processing that are inaccessible to consciousness, the knowledge-how acquired in this way is not belief-based but is based primarily on expertise acquired through perceptual learning. This type of knowledge-how contrasts with the type discussed in the previous section. Recall that if we were

to ask why the novice *s* added onion, tomato paste, cardamom, and chiles to the heated ghee in the pot, it would suffice to provide a personal-level explanation to the effect that he did this because he wanted to cook a potful of Chicken Tikka Masala and believed that these step were necessary to reach the desired outcome. But were we to ask why the chicken-sexer squeezed the chick the way he did, we could not offer the personal-level explanation that he wanted to determine its sex and believed that squeezing it just as little or as much as he did was necessary in order to reach the desired outcome. What drives the acquisition of know-how in cases of perceptual learning is the exercise of enhanced perceptual abilities, not the subject's beliefs about which steps will lead to the desired outcome. So, for cases of knowledge-how that are based on perceptual learning, anti-intellectualism provides a better model than intellectualism of the acquired knowledge-how.

A special case of perceptual learning is proprioceptive learning (Bilodeau & Bilodeau, 1961; Krakauer, et al. 1999; Dayan & Cohen, 2011; Avraamides, et al., 2014). Proprioception is a perceptual sense of the relative position of different parts of one's body and the effort required in order to perform certain movements. It is 'perceptual' in the sense that it consists of sensory signals about body parts and their movements provided by receptors in muscles, tendons, and joints. Knowing how to walk, write, ride a bicycle or perform a quadruple salchow is the result of expertise obtained through extensive proprioceptive learning and muscle memory. So is the ability to enter your password to unlock your computer without having to think about it, and indeed sometimes even without possessing the ability to verbally reproduce the password.

Once proprioceptive knowledge has been acquired, it can be retained over extended periods of time or forgotten (Dayan & Cohen, 2011). Retention typically owes to changes in the brain's gray and white matter. An increase in gray matter has been found in the occipital and parietal lobes of the brain following six weeks of juggling practice (Scholz et al., 2009), in the bilateral occipito-temporal cortex after seven days of juggling practice (Driemeyer et al., 2008), and in parieto-frontal regions following two weekly practice sessions in a whole-body balancing task (Taubert et al., 2010).

As processes that are grounded in structural changes in the brain's gray matter are inaccessible to consciousness, the knowledge-how acquired on the basis of these changes is not belief-based. Rather, this type of knowledge-how is acquired as a result of proprioceptive learning and related motor skill learning. What drives the acquisition of know-how in these cases is the acquisition of new proprioceptive abilities as well as new motor abilities. So, for these cases of know-how, anti-intellectualism provides a better model of knowledge-how to do things than does intellectualism.

5. Conclusion

There has been a lot of recent debate about whether knowledge how to do things is best accounted for on an intellectualist or an anti-intellectualist model. On the standard way of distinguishing the two views, intellectualism is the view that knowledge how to do something requires knowing that a particular procedure will bring about the desired outcome, whereas the anti-intellectualism is the view that knowledge-how to do something requires practical abilities

the exercise of which will bring about the desired outcome. In this paper I have argued that there is a better way of drawing the distinction between intellectualism and anti-intellectualism. A closer look at different types of knowledge-how reveals that there are two types of knowledge-how, and that different models are required to account for them. One type of knowledge-how requires the acquisition of an explicit or implicit (true) belief that a particular procedure will lead to the desired end result, together with pre-existing practical abilities to follow the procedure. The other type of knowledge-how does not require any belief that a particular procedure will lead to the desired outcome but requires the ability to exercise skills grounded in perceptual or proprioceptive learning.

A culinary novice may correctly be said to know how to cook a potful of Chicken Tikka Masala if he is able to successfully follow a recipe that he correctly believes will lead to the desired end result. In addition to the belief that following the recipe will result in a potful of Chicken Tikka Masala, he will also need to rely on pre-existing practical abilities to follow each step (e.g., the ability to add opinion to the pot). Intellectualism offers a good account of this type of knowledge-how.

In order for someone to possess the knowledge of how to determine the sex of a chick, on the other hand, one need not know each step of the procedure that can lead to this outcome. A chicken sexer merely needs to have the expert vision and touch that can lead him to conclude with high accuracy that the chick is male or female. For the latter type of knowledge-how, having the ability to consciously access information about the procedure that needs to be employed in order for the desired outcome to be brought about isn't required. So, anti-intellectualism provides a fair account of this type of knowledge-how.

It should be noted that while one can differentiate two types of knowledge-how, most cases of knowledge-how presumably are mixed cases. Consider the case of riding a bicycle from Coconut Grove to Key Biscayne. In addition to the knowledge-how that ensues from proprioceptive learning, this feat might require, for instance, knowledge of how to retrieve the bike from the bike cellar and knowledge of how to use Google Maps to retrieve directions from Coconut Grove to Key Biscayne. The latter two pieces of knowledge-how may very well be a kind of belief-based knowledge-how rather than the result of utilizing information that stems from perceptual or proprioceptive learning.[3]

References

Ahissar M & Hochstein S. (1993). "Attentional control of early perceptual learning," *Proceedings of the National Academy of Sciences*, 90, 12: 5718–5722.

Avraamides MN, Sarrou M, Kelly JW. (2014) "Cross-sensory reference frame transfer in spatial memory: the case of proprioceptive learning," Mem Cognit. 2014 Apr;42(3):496-507.

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Bengson, J. and M. Moffett. (2007). “Know-How and Concept-Possession”, *Philosophical Studies* 136: 31-57.

Bengson, J. and M. Moffett. (2011). "Non-propositional Intellectualism," in *Knowing How: Essays on Knowledge, Mind, and Action*, J. Bengson and M. Moffett eds., Oxford: Oxford University Press (2011): 161–195.

Biederman, I. & Shiffrar, M. M. (1987). “Sexing Day-Old Chicks: A Case Study and Expert Systems Analysis of a Difficult Perceptual-Learning Task,” *Journal of Experimental Psychology: Learning, Memory, and Cognition* 13(4): 640-645.

Bilodeau, E A & Bilodeau, I M (1961). “Motor-Skills Learning,” *Annual Review of Psychology* 12: 243-280.

Brogaard, B. 2007. “Attitude Reports: Do you Mind the Gap?”, *Philosophy Compass* xxxx.

Brogaard, B. 2008. “Knowledge-The and Propositional Attitude Ascriptions,” in *Knowledge and Questions*, ed. Franck Lihoreau, *Grazer Philosophische Studien* 77: 147-190.

Brogaard, B. (2009). “What Mary Did Yesterday: Reflections on Knowledge-wh,” *Philosophy and Phenomenological Research* 78: 439-467.

Brogaard, B. (2011). “Knowledge-How: A Unified Account”, Knowing How: Essays on Knowledge, Mind, and Action, J. Bengson and M. Moffett eds., Oxford: Oxford University Press (2011): 136-160.

Brooks LR, Norman GR, Allen SW. (1991). “Role of Specific Similarity in a Medical Diagnostic Task,” *J. Exp. Psychol. Gen.* 120: 278-87.

Burns B, Shepp BE. (1988). “Dimensional interactions and the structure of psychological space: the representation of hue, saturation, and brightness.” Percept Psychophys. 1988 May;43(5):494-507.

Carter, JA & Pritchard, D (2015a). “Knowledge-How and Cognitive Achievement”, *Philosophy and Phenomenological Research* 91 (1):181-199.

Carter, JA & Pritchard, D (2015b). “Knowledge-How and Epistemic Value”, *Australasian Journal of Philosophy* 93 (4):799-816.

Carter, JA & Pritchard, D (2015c). “Knowledge-How and Epistemic Luck”, *Noûs* 49 (3):440-453.

Cath Y. (2011). “Knowing How Without Knowing That.” In John Bengson & Mark Moffett (eds.), *Knowing How: Essays on Knowledge, Mind, and Action*. Oxford University Press pp. 113–35.

Cath, Y. (2015). “Revisionary Intellectualism and Gettier.” *Philosophical Studies* 172 (1):7-27.

Chase, W. G., & Simon, H. A. (1973a). “The Mind’s Eye in Chess.” In W. G. Chase (Ed.), *Visual Information Processing* (pp. 215-281). New York: Academic Press.

Chase, W. G., & Simon, H. A. (1973b). “Perception in Chess,” *Cognitive Psychology* 4, 55-81.

Dayan, Eran; Cohen, Leonardo G (2011). Neuroplasticity Subserving Motor Skill Learning, Neuron 72.3: 443-454.

Dennett, D. C. (1969). *Content and Consciousness*, London: Routledge & Kegan Paul.

Driemeyer J, Boyke J, Gaser C, Büchel C, May A, (2008). “Changes in gray matter induced by learning--revisited,” *PLoS ONE*, Vol. 3, 2008, e2669.

Gibson JJ & Gibson EJ. (1955). “Perceptual Learning: Differentiation or Enrichment?”, *Psychol. Rev.* 62: 32-41.

Gobet, F. & Simon, H. A. (1996). “Templates in Chess Memory: A Mechanism for Recalling Several Boards,” *Cognitive Psychology*, 31, 1-40.

Gobet, F. & Simon, H. A. (2000). “Five Seconds or Sixty? Presentation Time in Expert Memory,” *Cognitive Science*, 24, 651-682.

Goldstone, RL. (1998). “Perceptual Learning,” *Annual Review of Psychology* Vol. 49: 585-612.

Hennig M.H., Kerscher N.J., Funke K. , Wo F. (2002). Stochastic resonance in visual cortical neurons: Does the eye tremor actually improve visual acuity? Neurocomputing, 44 (2002), pp. 115–120

Kellman PJ & Garrigan P. (2009). “Perceptual Learning and Human Expertise,” *Phys Life Rev.* 6(2): 53-84.

Krakauer JW, Ghilardi M-F, Ghez C. (1999) Independent learning of internal models for kinematic and dynamic control of reaching John W. Krakauer1, Maria-Felice Ghilardi2,3 & Claude Ghez3 Nature Neuroscience 2, 1026 - 1031 (1999) doi:10.1038/14826

Levy, N. (forthcoming). “Embodied Savoir-Faire: Knowledge-How Requires Motor Representations.” Synthese

McKee, S. P. & Westheimer, G. (1978). “Improvement in Vernier Acuity with Practice,” *Perception & Psychophysics*, 24, 258-262.

Palmeri TJ, Goldinger SD, Pisoni DB. (1993). Episodic Encoding of Voice Attributes and Recognition Memory for Spoken Words," *J. Exp. Psychol.: Learn. Mem. Cogn.* 19: 309-328.

Saarinen, J. & Levi D.M. (1995). "Perceptual learning in vernier acuity: What is learned?" Vision Research, 35 (4) 519–527.

Scholz J, Klein MC, Behrens TE, Johansen-Berg H (2009). "Training Induces Changes in White-Matter Architecture," *Nat. Neurosci.* 12: 1370-1371.

Schyns PG, Murphy GL. 1994. The ontogeny of part representation in object concepts. In The Psychology of Learning and Motivation, ed. DL Medin, 31:305-54. San Diego: Academic.

Snowdon, P. (2003). "Knowing How and Knowing That: A Distinction Reconsidered," *Proceedings of the Aristotelian Society* 104: 1-29.

Stadler, M.A.(1989). "On Learning Complex Procedural Knowledge." *Journal Of Experimental Psychology: Learning, Memory, and Cognition*, Vol.15, No.6 pgs. 1061-1069.

Stanley, J. & Williamson, T. (2001). "Knowing How," *Journal of Philosophy* 98: 411-44.

Taubert M, Draganski B., Anwander A., Müller K., Horstmann A., Villringer A., Ragert, P. (2010). "Dynamic Properties of Human Brain Structure: Learning-Related Changes in Cortical Areas and Associated Fiber Connections," *J. Neurosci.* 30: 11670-11677.

Westheimer, G. (1975). "Visual Acuity and Hyperacuity," *Investigative Ophthalmology* 14: 570–572.

Westheimer, G & McKee, S.P. (1978). "Stereoscopic Acuity for Moving Retinal Images" *Journal of the Optical Society of America* 68 (4): 450–455.