

MORE ROOTS OF COMPLEMENTARITY:  
KANTIAN ASPECTS AND INFLUENCES

Introduction

MUCH HAS been written about Niels Bohr's philosophy of complementarity.<sup>1</sup> One point of agreement among these analyses is that Bohr's complementarity primarily concerns epistemology and not ontology. Bohr was certainly one of the most philosophical physicists of this century; his critical interest in the form and construction of knowledge elicits comparison with Immanuel Kant's highly influential epistemology. On the face of it, there seem to be several similarities between Bohr's complementarity and Kant's epistemology. For example, both share a distinction between observable and unobservable objects, and an acute attention to the conditions surrounding experience and empirical knowledge. Indeed, given the overriding dissemination of Kantian philosophy throughout Europe during the nineteenth century, one might be surprised by a *lack* of Kantian aspects in Bohr's writings.<sup>2</sup>

Yet the common reaction among commentators on complementarity is to downplay any similarities with Kant. Three of the most comprehensive treatments of complementarity dismiss connections with Kant: Gerald Holton omits all mention of Kant in his discussion of the roots of complementarity, Dugald Murdoch makes merely passing references to a shared spirit of pragmatism between Kant and Bohr, while Henry Folse outright denies any substantive connections whatsoever.<sup>3</sup> Even more striking is Abraham Pais' recent claim that 'Bohr never cared much for, nor knew much of, what professional philosophers had to say. Occasional attempts to trace the origins

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<sup>1</sup>Cf. e.g. Hooker 1972, Fay 1979, Folse 1985, Murdoch 1987, and Holton 1988. Holton's chapter 'On The Roots Of Complementarity' originally appeared in *Daedalus* 99 (1970), 1015-1055.

<sup>2</sup>Köhnke (1986) provides an analysis of the origins and rise of neo-Kantianism during the nineteenth century. The extent to which neo-Kantianism influenced philosophical and scientific circles should not be underestimated. Even the early (pre-1930) work of the logical positivists reflected the overwhelming influence of Kant: Michael Friedman has shown that, in spite of anti-Kantian rhetoric, both Rudolf Carnap and Moritz Schlick stood closer to Kant's philosophy and neo-Kantianism than to traditional empiricism in their writings from the 1920s. Cf. Friedman 1983, Friedman 1987, and Rouse 1991.

<sup>3</sup>Cf. Holton 1988, pp. 99-145; Murdoch 1987, pp. 229-231; and Folse 1985, pp. 217-221.

of Bohr's complementarity to their writings are without basis in fact'.<sup>4</sup> None of these accounts, however, critically examines possible Kantian aspects of complementarity. In fact, none of them offers any comparison with text from Kant's actual writings. At most, vague sentence- or paragraph-long synopses of Kantian philosophy are supplied and claimed to be opposed to the core of complementarity.

This paper presents a re-examination of the philosophical similarities between Bohr's complementarity and Kant's epistemology. Detailed comparison of some of Kant's important writings with Bohr's articles and correspondence about complementarity reveals an essential parallelism concerning several philosophical aspects. For instance, they share a distinction, common throughout the history of philosophy, between unobservables and experienced phenomena. Yet Bohr's complementarity surpasses the mere distinction, and shares Kant's *actual mechanism* for guaranteeing the objective reality of our judgments.

There are two major reasons why the previous accounts have either failed to recognize or have denied similarities between Bohr and Kant. One is the failure to distinguish between *separate aspects* of Kant's philosophy. Bohr's complementarity embodies some Kantian features while rejecting others; the rejection of some aspects by Bohr has been wrongly taken as evidence of a complete rejection of Kant. The other reason arises from a conflation of philosophical aspects with historical influences. Many authors cite a lack of historical evidence of Kantian influences on Bohr as evidence against similarities between their respective philosophies. Yet, as in literature, there could exist deep parallels between the two philosophies without an accompanying theory of causation. And, in fact, there appear to have been at least two distinct channels through which Bohr gained exposure to Kant's writings: the texts of the American philosopher and psychologist William James, and Bohr's lifelong friendship with the Danish philosopher Harald Høffding.

### Kant: Ending a Civil War and Rescuing Metaphysics

#### *Two Faculties of Knowledge: Sensibility and Understanding*

In the *Critique of Pure Reason*, Kant was most concerned with the question of metaphysics: how is metaphysics possible? Although metaphysics was once considered 'the Queen of all the sciences', it had not yet, according to Kant, 'had the good fortune to enter upon the secure path of a science'.<sup>5</sup> Kant perceived his predecessors as fighting a civil war: on one side were Locke and

Hume arguing for empiricism, on the other side Leibniz and Berkeley fighting for rationalism. L. W. Beck has described Kant's strategy for ending this civil war:

In cases where two opposed arguments seem internally sound but where their conclusions are incompatible and hence a stalemate is created . . . "[i]t is a heuristic maxim that the truth lies not in one of the two disputed views but in some third possibility which has not yet been thought of, which we can only discover by rejecting something assumed as obvious by both the disputants". ["Ramsey's Maxim"] Two theories, X and non-X, may be reconciled or *both* refuted by finding that they have a common false element.<sup>6</sup>

The 'common false element' that Kant found inherent in empiricism and rationalism was the belief that knowledge arises from only one source or faculty.<sup>7</sup> For the rationalists, that single faculty was the intellect; for the empiricists it was sensory intuition. As Beck summarizes: 'Leibniz, [Kant] tells us, intellectualized appearances while Locke sensualized all the concepts of the intellect'.<sup>8</sup> Kant's solution was his landmark bifurcation of knowledge into *two* faculties: sensibility (or intuition) and understanding. In Kant's own words:

Without sensibility no object would be given to us, without understanding no object would be thought. *Thoughts without content are empty, intuitions without concepts blind.* It is, therefore, just as necessary to make our concepts sensible, that is, to add the object to them in intuition, as to make our intuitions intelligible, that is, to bring them under concepts. These two powers or capacities cannot exchange their functions. The understanding can intuit nothing, the senses can think nothing. Only through their union can knowledge arise.<sup>9</sup>

The failure to recognize the necessary interplay between the faculty of intuition and the faculty of the understanding was the reason for the failure of both forms of epistemology, empiricism and rationalism alike, to establish a secure foundation of metaphysics.<sup>10</sup>

<sup>4</sup>L. W. Beck 1978, p. 11. Beck's quotation is of 'Ramsey's Maxim', from Ramsey 1931, pp. 115-116. Beck prefaces this remark by writing that 'Kant did not tell us his strategic secrets, and perhaps he was not fully aware of his strategem' (Beck 1978, p. 11). Yet in his discussion of the Antinomies, Kant did in fact explicitly note his strategy: 'If two opposed judgments presuppose an inadmissible condition, then in spite of their opposition . . . , both fall to the ground, inasmuch as the condition, under which alone either of them can be maintained, itself falls.' (Kant 1929, p. 446 [A503/B531].)

<sup>5</sup>Beck 1978, p. 12.

<sup>6</sup>Beck 1978, p. 12. Ian Hacking provides a very similar synopsis of Kant's strategy in Hacking 1983, pp. 95-97. An interesting description of the contrast between the single-faculties of the empiricists and the rationalists with Kant's two-faculty system is given in Brittan 1978: the former programs are outlined as 'reductionist', while Kant's method is 'anti-reductionist'. Cf. Brittan 1978, pp. 6-10.

<sup>7</sup>Kant 1929, p. 93 (A51/B75). Emphasis added.

<sup>8</sup>Cf. Kant 1929, p. 25 (Bxxii), 93 (A51/B75).

<sup>4</sup>Pais 1991, p. 24.

<sup>5</sup>Kant 1929, pp. 7 (Aviii), 21 (Bxiv). I will often refer below to the *Critique of Pure Reason* simply as the *Critique*.

*Kant's 'Copernican Revolution'*

By solving one problem, Kant created a new one. He now had to deal with the problem of the relation between objects and our representations of them, that is, with the problem of objective reference. Kant described his dilemma in 1772: '... I asked myself: On what ground rests the relation of that in us which is called representation to the object?'<sup>11</sup> The empiricists had offered one solution: they based representations upon the *passive* affections of our senses. According to this view, the object makes the representation possible; there is no possibility for *a priori* knowledge. Kant termed his option of pure receptivity the *intellectus ectypus*.<sup>12</sup> The rationalists had offered a different solution: they founded representations upon the *active* creations of the understanding. In this way, the rationalists argued that the representation makes the object itself possible. For the rationalists, the archetypal or ideal case would be Divine knowledge; human knowledge is merely a confused and incomplete rendering of the archetype. Kant labeled this position *intellectus archetypus*.<sup>13</sup>

In 1772, Kant was still unclear about how to solve the question of objective reference: '[T]his question, of how the faculty of the understanding achieves this conformity with the things themselves, is still left in a state of obscurity'.<sup>14</sup> Kant's solution was to come nine years later, a solution he labelled his 'Copernican Revolution' in the *Critique of Pure Reason*:

If intuition must conform to the constitution of the objects, I do not see how we could know anything of the latter *a priori*; but if the object (as object of the senses) must conform to the constitution of our faculty of intuition, I have no difficulty in conceiving such a possibility . . . I assume that the *objects*, or what is the same thing, that the *experience* in which alone, as given objects, they can be known, conform to the concepts.<sup>15</sup>

Again, Kant found a solution in the rejection of a common false element: the shared notion that our representations are of objects as 'things in themselves'. The supposition, held by both sides, that our empirical knowledge conforms to things in themselves leads to contradictions. On the other hand, when 'we suppose that our representation of things, as they are given to us, does not conform to these things as they are in themselves, but that these objects, as appearances, conform to our mode of representation, *the contradiction vanishes* . . .'<sup>16</sup> That is, our concepts take priority, not because objects do not exist in themselves, but because we can never know them 'in themselves'. In this way, Kant erected his transcendental distinction between appearances and things in

<sup>11</sup>Letter from Kant to Marcus Herz, 21 February 1772. Translated and reprinted in Beck 1965, p. 231.

<sup>12</sup>*Ibid.*

<sup>13</sup>*Ibid.*

<sup>14</sup>*Ibid.*, p. 232.

<sup>15</sup>Kant 1929, p. 22 (Bxvii). Emphasis added.

<sup>16</sup>*Ibid.*, p. 24 (Bxx).

themselves. His Copernican Revolution thus spawned two Kantian aspects: *a priori* and the distinction between phenomena and noumena.

*Two Kantian Aspects: A Priorism and the Phenomena–Noumena Distinction*

With his Copernican Revolution, Kant rescued the possibility of having knowledge of objects *a priori*: 'we can know *a priori* of things only what we ourselves put into them'.<sup>17</sup> Kant wrote in the 'Transcendental Aesthetic' that the faculty of intuition may sensibly intuit objects only once representations of the objects are made to conform to space and time, that is, once they conform to the *a priori* forms of our intuition. In this sense, the faculty of intuition acts as a filter in our collection of sense data, allowing only what is given in space and time to be experienced.

After the faculty of intuition makes the reception of these appearances possible, the faculty of the understanding formulates concepts of the objects and relates these concepts in judgments. The judgments are governed by the *a priori* rules for all judgments, the 'categories'. Thus, just as space and time are *a priori* forms of intuition, making the formation of intuitions possible, the categories are *a priori* forms of the understanding, making the formation of judgments possible.

Kant believed that the *a priori* forms of intuition and categories may be delineated once and for all. For example, he claimed that his transcendental deduction of the twelve categories was a complete articulation, and was 'not to be increased by any additions from without'.<sup>18</sup> As proof of such completeness, Kant included a 'Table of Categories' which 'yield[ed] an exhaustive inventory' of the pure concepts of the understanding.<sup>19</sup> Thus, Kant considered our conceptual framework to be *unalterable*: in addition to being independent of experience, the forms of intuition and categories are necessary, universal, and completely specifiable; there is neither need nor possibility to add to or subtract from his lists. This aspect of Kant's philosophy has been referred to as *a priorism*.

For Kant, the possibility of *a priori* knowledge of objects required a distinction between objects as appearances and objects in themselves. '[T]his deduction of our power of knowing *a priori* . . . has a consequence which is startling . . . For we are brought to the conclusion that we can never transcend the limits of possible experience . . . [Our knowledge] has to do only with appearances, and must leave the thing in itself as indeed real per se, but as

<sup>17</sup>*Ibid.*, p. 23 (Bxviii).

<sup>18</sup>*Ibid.*, p. 102 (A65/B90).

<sup>19</sup>*Ibid.*, p. 113 (A80–81/B105–6).

not known by us'.<sup>20</sup> This introduces the second Kantian aspect to be treated here: the distinction between phenomena and noumena.

Phenomena and noumena were defined by Kant in terms of the possibility of experience: phenomena are objects of possible experience, while noumena are things in themselves, forever outside the domain of possible experience.<sup>21</sup> Kant reiterated his phenomena–noumena distinction throughout the *Critique of Pure Reason*, as well as in several other writings. For example, in the *Prolegomena* Kant wrote that 'we can know objects only as they appear to us (to our senses), not as they are in themselves'.<sup>22</sup> Noumena as objects of possible thought are admitted,

but with the inculcation of this rule which admits of *no exception*: that we neither know nor can know anything determinate whatsoever about these pure beings of the understanding [noumena], because our pure concepts of the understanding as well as our pure intuitions extend to nothing but objects of possible experience, consequently to mere things of sense [phenomena]; and as soon as we leave this sphere, these concepts retain no meaning whatsoever.<sup>23</sup>

Thus, the thrust of Kant's phenomena–noumena distinction is the limitation of all empirical knowledge to objects of possible experience.

Clearly, these two aspects of Kant's philosophy, *a priorism* and the phenomena–noumena distinction, are deeply bound together and interconnected. For example, as cited above, Kant discussed the phenomena–noumena distinction as a 'startling consequence' of 'our power of knowing *a priori*'. Yet they are not inextricable. Each Kantian aspect may be dealt with on its own, and one may be accepted (with suitable provisions) while the other is rejected. Historically, we will see that this is precisely what Bohr did. But before turning to Bohr, let us look at Kant's mechanism for ensuring the objective reality of judgments.

### Conceptual Containment

In the *Critique of Pure Reason*, Kant discussed how to ensure that a given judgment is objectively or 'unconditionally valid' with respect to empirical knowledge. This is the same as ensuring the objective reality of a given judgment. A judgment may be deemed unconditionally or universally real if 'we add to the concept of the subject of a judgment *the limitation under which*

<sup>20</sup>*Ibid.*, pp. 23–24 (Bxix–Bxx). Emphasis added.

<sup>21</sup>*Cf. ibid.*, pp. 266–268 (B306–7).

<sup>22</sup>Kant 1985, p. 27 (Ak. 283).

<sup>23</sup>*Ibid.*, pp. 57–58 (Ak. 315). Emphasis added. This positive rendering of noumena as 'objects of possible thought' is supported in the *Critique of Pure Reason* by Kant's footnote on p. 27 (Bxxv): one may think whatever one pleases, so long as the thought is not self-contradictory. This is, of course, very different from ascribing objective reality to the thought, which may only be done with properly contained judgments referring to objects of possible experience.

*the judgment is made*'.<sup>24</sup> In other words, if we contain a concept, such that the only conditions allowed as possible are those under which judgments about the concept will be valid, then any judgment concerning that (contained) concept will be objectively real. This is the same as including within the concept itself the conditions and limitations under which the concept is made. I term this mechanism Kant's *conceptual containment*.

It should be noted that Kant's discussion of the objective reality of judgments in his *Prolegomena* is different from that which he supplied in the B-edition of the *Critique*. The importance of the difference between the arguments can be partially remedied here by noting that his *conclusion* was the same in each case: to maintain objective reality, a judgment must be properly contained, with the inclusion of the 'limitation under which the judgment is made'.

In the *Prolegomena*, Kant made the distinction between 'judgments of experience', which do have objective reality, and 'judgments of perception', which he wrote are merely subjectively or contingently valid. In the B-edition of the *Critique*, however, Kant changed this altogether, such that *all* judgments are necessarily *objectively* valid. The meaningful question concerns whether or not judgments are objectively *real*. As in the *Prolegomena*, Kant again concluded that judgments may only be objectively real if they are properly contained.<sup>25</sup>

There are countless examples throughout the *Critique* of the use of conceptual containment.<sup>26</sup> In the section entitled 'The Ground of the Distinction of all Objects in General into Phenomena and Noumena', Kant remarked:

[N]o object is determined through a pure category in which abstraction is made of every condition of sensible intuition . . . the employment of a concept involves a function of judgment whereby an object is subsumed under the concept, and so involves at least the formal condition under which something can be given in

<sup>24</sup>Kant 1929, p. 72 (A27/B43). Emphasis added. This is the only reference I have found in which Kant *explicitly* stated his strategy for what I have termed conceptual containment, although he made repeated use of it. This is a similar situation to Kant's once-stated yet often-used strategy which Beck has analyzed. Cf. footnote 6.

<sup>25</sup>*Cf. Kant* 1985, pp. 41–46 (Ak. 297–302). This point reduces to one of terminology for this discussion of the relation between objective reality and conceptual containment. Yet in a grander scope, it represents Kant's rejection of his own prior *subjectivism*. In the B-edition of the *Critique of Pure Reason*, Kant presented his philosophy as being completely *objective*: all judgments and empirical knowledge are necessarily objective, while fancies of the imagination retain mere subjective validity. (Cf. Kant 1919, p. 159 [B141–142].) Thus, Folse's complaint that 'some of the most perceptive of Bohr's interpreters [have written] that his position contains Kantian elements supporting a *subjectivistic* reading of complementarity' is not in itself evidence enough to neglect all Kantian aspects of Bohr's complementarity, for Kant himself rejected subjectivism. Cf. Folse 1985, p. 217.

<sup>26</sup>*Cf.*, e.g., Kant 1929, pp. 77–78 (A35–36/B51–52); p. 80 (A39/B56); pp. 189–190 (A150/B189–190); pp. 192–193 (A155–156/B194–195); pp. 298–299 (A295–296/B352–353); p. 391 (A416–417/B444); pp. 442–443 (A496–497/B524–525); p. 448 (A506/B534); p. 450 (A509–510/B537–538); pp. 483–484 (A565–566/B593–594); p. 554 (A676–677/B704–705).

intuition. If this condition of judgment . . . is lacking, all subsumption becomes impossible. For in that case nothing is given that could be subsumed under the concept. The merely transcendental employment of the categories is, therefore, really no employment at all . . .<sup>27</sup>

In other words, one must include the conditions under which an object is perceived in order for judgments regarding the object to remain meaningful. To attempt to form judgments relating uncontained concepts — to ignore the conditions and limitations of sensible intuition — would yield no empirical knowledge.

Conceptual containment, together with the limitation of knowledge to objects of possible experience, provide Kant's solution to the problems of metaphysics. We delude ourselves if we neglect conceptual containment and attempt to gain knowledge of things in themselves: '[I]f I ascribe redness to the rose in itself, or extension to all objects in themselves, without paying regard to the *determinate relation of these objects to the subject*, and *without limiting my judgment to that relation*, illusion then first arises'.<sup>28</sup> It is this type of illusion which underlies the Antinomies of Pure Reason. Kant explained:

The ideas [cosmological ideas of the four antinomies] are such that an object congruent with them can never be given in any possible experience . . . Yet they are not arbitrarily conceived. Reason . . . is necessarily led to them whenever it *endeavours to free from all conditions* and apprehend in its unconditioned totality that which according to the rules of experience *can never be determined save as conditioned*.<sup>29</sup>

Each of the four antinomies is characterized by *uncontained concepts*. By recognizing this, the 'self-conflict of reason will be entirely at an end'.<sup>30</sup> Thus, Kant's critical solution to the antinomies rendered them harmless, and provided metaphysics the secure path of a science. In so doing, Kant believed that he had fulfilled his primary goal of rescuing metaphysics.

### Bohr's Rejection of Kantian *A Priorism*

#### *Bohr's Kantian Antithesis between Sensibility and Understanding*

Kant's limitation of knowledge to objects of possible experience, leaving things in themselves real but unknowable, provides an obvious indication of a Kantian aspect of Bohr's complementarity. Bohr's attention to the details of measurement led to his own criterion linking knowledge to the domain of

<sup>27</sup>*Ibid.*, pp. 264–265 (A247–B304).

<sup>28</sup>*Ibid.*, p. 89 (B70). Emphasis added.

<sup>29</sup>*Ibid.*, p. 422 (A462/490). Emphasis added.

<sup>30</sup>*Ibid.*, p. 454 (A516/B544).

possible experience.<sup>31</sup> To Bohr, physics depended upon communicable, objective descriptions of the world. Bohr's task was to guarantee that the quantum realm remained describable: physicists must be able to discuss their research with quantum phenomena with the same clarity as they could discuss experiments and observations from classical physics. This could only be accomplished, argued Bohr, if physicists adopted the language of classical physics to discuss quantum phenomena. To 'tell others what we have learned' from an experiment, we must express both our experimental arrangements and the results of our observations 'in unambiguous language with suitable application of the terminology of classical physics'.<sup>32</sup>

Yet physicists were aware throughout the earliest quarter of this century that quantum phenomena do not behave like classical phenomena. Results from contrasting experimental arrangements incurred widely varying classical descriptions. One of the most familiar examples of this involves light: the interference pattern obtained when light passes through a diffraction grating may be described in much the same way as the interference pattern obtained when water waves pass through holes in a barrier. In other words, the interference behavior of light can be explained in terms of classical wave theory. But wave descriptions fail to explain the behavior of light in the photoelectric effect: the ejection of electrons from a metal illuminated by light is best described in terms of particles, much as physicists describe the classical collisions of billiard balls. Thus, the physical description of light requires the use of classical wave explanations in some experimental arrangements, and classical particle explanations in others. This has been termed wave-particle duality: the way physicists talk about light alternates between wave-like and particle-like explanations from experiment to experiment. No experiment has ever successfully revealed both types of behavior simultaneously.

Bohr introduced his philosophy of complementarity to reconcile these divergent physical descriptions. He explained that in the quantum realm we must 'adopt a new mode of description designated as *complementary* in the sense that any given application of classical concepts *precludes the simultaneous use* of other classical concepts which in a different connection are *equally necessary for the elucidation* of the phenomena'.<sup>33</sup> We must use classical concepts in order to discuss the quantum realm objectively, but these concepts now stand in a new relationship to one another. The wave-particle duality of light, for example, invokes mutually exclusive concepts relating to either wave

<sup>31</sup>Thus, even in his discussion of *gedanken*-experiments, Bohr would include full depictions of the measuring apparatus appropriate for the imagined physical situation. The diagrams accompanying his 1949 article about his debate with Einstein over quantum theory are especially illustrative of this attention to the conditions surrounding observation. Cf. Bohr 1949.

<sup>32</sup>Bohr 1949, p. 210. Also quoted in Holton 1988, p. 103.

<sup>33</sup>Bohr 1934, p. 10. Emphasis added.

behavior or particle behavior. The wave descriptions necessary to account for interference experiments cannot be replaced by particle descriptions. Yet the particle descriptions are 'equally necessary for the elucidation' of light's behavior: the classical particle concepts cannot be replaced by wave concepts when describing the photoelectric effect. The classical concepts are mutually exclusive, yet both are required to produce a complete explanation of the phenomena. In other words, particle concepts and wave concepts are complementary.<sup>34</sup>

Bohr described complementarity with language highly reminiscent of Kant's, both in substance and style. For example, he wrote of our 'forms of perception' and 'modes of perception' when describing how we gain sensory experience: 'we must remember . . . that . . . all new experience makes its appearance within the frame of our customary points of view and forms of perception'.<sup>35</sup> Bohr continued, '[W]e can by no means dispense with those forms of perception which colour our whole language and in terms of which all experience must ultimately be expressed'.<sup>36</sup> Dugald Murdoch, who largely dismisses the significance of connections between Bohr and Kant, still admits that the 'Kantian character of this view is unmistakable: the forms of perception are the preconditions of the possibility of our sensory experience and of the meanings of the words we use to describe it . . .'.<sup>37</sup>

Bohr, like Kant, advocated a two-faculty epistemology. For example, he wrote that 'no content can be grasped without a formal frame and that any form, however useful it has hitherto proved, may be found to be *too narrow to comprehend new experience*'.<sup>38</sup> There is an essential interaction, wrote Bohr, between the faculty of intuition, supplying the 'content', and the faculty of the understanding, providing the 'formal frame' with which to 'grasp' the experience. This statement is comparable with Kant's famous introduction to the 'Transcendental Aesthetic': 'There can be no doubt that all our knowledge begins with experience . . . But though all our knowledge begins with experience, it does not follow that it all *arises out of experience*'.<sup>39</sup>

Yet there is also a very un-Kantian sentiment expressed in the end of Bohr's quotation: our formal frame might need to be *altered*. As explained above, Kant viewed this formal frame, which includes the forms of intuition and the categories, as *a priori* and unalterable. Bohr followed a two-faculty format but he rejected *a priori*ism. For example, he argued that: '[N]o experience is

<sup>34</sup>This discussion is certainly not intended to elucidate the full meaning or implications of complementarity, but is included only as an introduction to Bohr's philosophy. For more on complementarity, see especially Folse 1985 and Murdoch 1987.

<sup>35</sup>Bohr 1934, p. 1.

<sup>36</sup>*Ibid.*, p. 5.

<sup>37</sup>Murdoch 1987, pp. 73–74.

<sup>38</sup>Bohr 1949, pp. 239–240. Emphasis added.

<sup>39</sup>Kant 1929, p. 41 (B1). Emphasis added.

definable without a logical frame and . . . any apparent disharmony can be removed only by an *appropriate widening* of the conceptual framework'.<sup>40</sup> Furthermore, 'As our knowledge becomes wider, we must always be prepared, therefore, to *expect alterations* in the points of view best suited for the ordering of our experience'.<sup>41</sup> Such a sentiment would have been incomprehensible to Kant. Bohr employed the Kantian eternal antithesis between the sensible and the rational while abandoning Kant's *a priori*ism.

#### *Folse's Argument concerning Bohr's Rejection of A Priorism*

On the basis of Bohr's rejection of a *a priori*ism, Henry Folse argues that there are no substantive Kantian aspects of Bohr's complementarity.<sup>42</sup> His argument is threefold: (1) because Bohr rejects Kant's *a priori*ism, complementarity cannot be Kantian; (2) because Bohr did not share Kant's philosophical intentions, their philosophies must be fundamentally different; and (3) the influence upon Bohr by the anti-Kantian philosopher William James precludes any Kantian aspects in Bohr's philosophy. Let us consider these arguments in turn.

In order to establish Bohr's rejection of Kant, Folse quotes from correspondence between Bohr and Wolfgang Pauli, claiming that in the following passage '[Bohr] distinguished his position from the "critical philosophy" of Kant':<sup>43</sup>

. . . I may for a moment remind of the days of so-called "classical" physics and "critical" philosophy, when in the description of the course of events the role of the tools of observation was disregarded and space-time co-ordination and causality were considered a priori categories. It is true that before the epistemological aspects of the problem were so widely cleared up, a certain confusion was prevalent, but after the thorough lesson which we have received, the whole situation including that of classical mechanics appears in a new light . . .<sup>44</sup>

While it is clear from this excerpt that Bohr rejected Kant's *a priori*ism, other aspects of Kant's philosophy were never even discussed by Bohr. In fact, Bohr did not mention Kant by name. Bohr merely distinguished his position from *a priori*ism.

<sup>40</sup>Bohr 1958, p. 82. Emphasis added.

<sup>41</sup>Bohr 1934, p. 1. Emphasis added.

<sup>42</sup>Folse offers the fullest argument against Kantian aspects of complementarity, although even this 'full' argument constitutes merely 5 pages of a 260 page text. Because Folse's treatment is the most comprehensive, however, and because he is the most adamant about the *lack* of Kantian aspects in complementarity, I will examine his argument closely.

<sup>43</sup>Folse 1985, p. 216.

<sup>44</sup>Letter (in English) from Bohr to W. Pauli, 25 March 1955. *Niels Bohr Archive: Bohr Scientific Correspondence*. reel 31; copies in the American Institute of Physics Niels Bohr Library, New York, NY, and other repositories of the Archives for the History of Quantum Physics (AHQP-AIP). This paragraph is also quoted in Folse 1985, p. 216.

But there is more to Kant's philosophy than a *priorism*. Folse neglects the possibility that one might accept certain aspects while abandoning others. Consider the following discussion:

Bohr regarded the critical philosophy as an attempt to prove the universality and necessity of the Newtonian framework by arguing that its concepts refer to forms imposed *a priori* on the formation of experienced phenomena by the preceiving subject. In order to understand why Bohr regarded the Kantian position (as he understood it) as opposed to complementarity, we must notice the very important fact that Bohr based his whole argument for the correct use of classical concepts on a *physical* theory, a purely *contingent* fact. It should be recognized at once that a true Kantian approach would never argue, as Bohr has argued, that such a physical discovery would demand a change in the proper use of the concepts which give experience its form.<sup>45</sup>

This argument is aimed exclusively at Bohr's rejection of a *priorism*, and has nothing to say about other possible connections between Kant's epistemology and Bohr's complementarity.

Folse's second argument focuses on Bohr's intent. Because Bohr, in developing complementarity, did not share Kant's epistemological intentions, the philosophies must be entirely different: 'it is *not* Bohr's intention that complementarity provides an account of how the subjectively intuited data of observation are furnished with conceptual form and thus synthesize the representations of experience. Yet this is precisely Kant's task'.<sup>46</sup> But must Bohr and Kant share the same intentions in order for their philosophies to have similar features? Indeed, Bohr did *not* share Kant's goal of rescuing metaphysics, but it does not necessarily follow that there are no Kantian aspects of complementarity. One may apply the same tools to differing tasks.

Perhaps Folse's strongest argument is his third: that Bohr testified in his lifetime to having been influenced by the American philosopher and psychologist William James, who was decidedly anti-Kant.<sup>47</sup> Indeed, James is one of only two philosophers in whose work Bohr expressed any interest in an interview the day before he died (the other was Harald Høffding). Bohr recalled that 'I read actually the work of William James. William James is really wonderful in the way that he makes it clear — I think I read the book, or a paragraph, called . . . "The Stream of Thoughts"'.<sup>48</sup> There has been some discrepancy regarding when Bohr was first exposed to James' work, although Folse has convincingly demonstrated that Bohr most likely read James during

<sup>45</sup>Folse 1985, p. 218.

<sup>46</sup>*Ibid.*, p. 219.

<sup>47</sup>On James' influence upon Bohr, Murdoch 1987, pp. 225–229, and Holton 1988, pp. 121–126, p. 131.

<sup>48</sup>Interview with Niels Bohr, conducted by Thomas S. Kuhn, Aage Petersen and Eric Rüdinger, 17 November 1962. Tape 36a: p. 6 of transcript; copies in AHQP–AIP. Hereafter I will refer to this transcript as 'Interview 1962'.

his student days at the University of Copenhagen, long before he formulated his philosophy of complementarity.<sup>49</sup>

Folse interprets this Jamesian influence as clear evidence that complementarity does not owe its origins to Kant:

[I]f in fact James' outlook expresses the direction from which Bohr's thought comes, then the imputation that complementarity is of Kantian origin would seem to be incorrect, for in the very chapter to which Bohr refers, 'The Stream of Consciousness', from *The Principles of Psychology*, James is arguing vehemently against the Kantian approach to the description of experience . . .<sup>50</sup>

Folse is correct that James argued against Kant, but in the chapter under discussion, James' 'vehement argument' is targeted exclusively at Kant's *a priorism*.

Throughout Chapter IX of *The Principles of Psychology*, entitled 'The Stream of Thought', James rejected Kantian *a priorism*. According to James, 'brain-physiology' establishes that one may never have the same sensation or thought, because this would require the actual physical brain to be in precisely the same state, an impossible requirement.<sup>51</sup> This is certainly contrary to Kant's unalterable, necessary, and universal *a priori* forms of intuition and categories. And indeed, James specifically took aim at Kant's *a priorism* throughout *The Principles of Psychology*. He called Kant's distinction between 'analytic' and 'synthetic' *a priori* truths 'one of Kant's most unhappy legacies', and then denied that there are 'any *a priori* truths'.<sup>52</sup> Moreover, James wrote that 'Kant . . . made a strange tactical blunder in his way of showing that the forms of our necessary thought are underived from experience [i.e. *a priori*]'.<sup>53</sup> James made it clear that he had no intention of making such a blunder.<sup>54</sup>

Yet despite his widespread onslaughts against Kant's *a priorism*, James quoted approvingly from the *Critique of Pure Reason* when discussing the perception of reality.<sup>55</sup> Clearly, James treated the various aspects of Kant's philosophy as *separable*. He attacked *a priorism* while approving of other

<sup>49</sup>Although Léon Rosenfeld claimed that Bohr did not read James' work earlier than 1932, Bohr himself emphasized that he first read James' work 'many years before' he worked in Manchester, that is, before 1912. (Interview 1962, p. 7.) Holton and Folse agree that most likely Bohr was referring to his student days, circa 1904. Both authors connect Bohr's first exposure to James with Harald Høffding, because Høffding and James visited each other in 1904, just the time when Bohr was enrolled in Høffding's philosophy course. Folse strengthens this stance by noting that Bohr explicitly linked his exposure to James with Edgar Rubin, who was a close friend and fellow student of Bohr's at the University of Copenhagen. Cf. Folse 1985, pp. 49–51, and Holton 1988, pp. 122–123, p. 128.

<sup>50</sup>Folse 1985, p. 49. Folse has made a mistake with the title of James' chapter. Bohr was actually correct: it is 'The Stream of Thought' and *not* 'The Stream of Consciousness'.

<sup>51</sup>James 1981, pp. 227–228, p. 239.

<sup>52</sup>*Ibid.*, p. 1255 (Chapter XXVIII).

<sup>53</sup>*Ibid.*, p. 1258 (Chapter XXVIII).

<sup>54</sup>Cf. *ibid.*, p. 603, p. 792, p. 909.

<sup>55</sup>*Ibid.*, p. 925 (Chapter XXI).

Kantian aspects, and purposely ignoring still others. Moreover, James separated himself and the field of psychology from most of the kinds of questions Kant dealt with:

In German philosophy since Kant the word *Erkenntnisstheorie*, criticism of the faculty of knowledge, plays a great part. Now the psychologist necessarily becomes such an *Erkenntnisstheoretiker*. But the knowledge he theorizes about is not the bare function of knowledge which Kant criticises — he does not inquire into the possibility of knowledge *überhaupt*.<sup>56</sup>

James explicitly offered a 'no comment' on most aspects of Kant's philosophy. Folse must therefore restrict his view of 'the Kantian approach' to a *priorism* in order to make his argument from James work:

Bohr certainly *thought* his position was in agreement with James, and by implication opposed to Kant's, which Bohr viewed as an *a priori* rationalist attempt to justify the universality and necessity of the framework of classical physics, the very view complementarity was designed to replace.<sup>57</sup>

Thus, the third portion of Folse's argument amounts to a premature conclusion regarding Bohr's complementarity based upon a rejection of only one specific Kantian aspect. The problem of influence must be treated more carefully: if Bohr was influenced by James' rejection of Kant's *a priorism*, he may well have been equally influenced to treat Kant's philosophy as separable. Let us turn to positive evidence concerning Kantian aspects of Bohr's complementarity.

### Kantian Aspects of Bohr's Complementarity

#### *Phenomena–Noumena Distinction in Bohr's Original Presentation of Complementarity*

Physicists Warner Miller and John Wheeler contend that 'Bohr's final word "*phenomenon*" — or, more specifically, "*elementary quantum phenomenon*"' comes closest to 'capturing the central new lesson of the quantum'.<sup>58</sup> Bohr's choice of the word 'phenomenon' to describe quantum mechanical situations certainly sounds reminiscent of Kant's 'phenomena' as objects of the senses or of possible experience. Bohr's choice of language is more than merely reminiscent of Kant's; it is in fact advanced in a completely Kantian fashion.<sup>59</sup>

<sup>56</sup>*Ibid.*, p. 184 (Chapter VII).

<sup>57</sup>Folse 1985, p. 49.

<sup>58</sup>Miller and Wheeler 1983, p. 140. Emphasis added.

<sup>59</sup>This is different from asserting that Bohr uses the word 'phenomenon' *intentionally* to establish a Kantian connection, especially because Bohr does not use other Kantian terminology such as 'noumenon'.

In the only surviving draft of his Como Lecture of 1927, Bohr discussed the observation problem in the quantum realm and its relation to epistemology.<sup>60</sup> Throughout the entire twelve-page manuscript, Bohr maintained a distinction between 'closed systems of objects' and 'phenomena':

[T]he idea of means of observation independent of the phenomena or of phenomena independent of means of observation cannot be maintained . . . On the one hand the exact definition of a system of objects claims the elimination of all external disturbances. But then according to the quantum postulate any *possibility of observation* will be excluded. On the other hand, if in order to make observation possible we permit *certain interactions* with suitable means of measurement, *not belonging to the system*, a rigorous definition of this system is naturally *no longer possible* . . .<sup>61</sup>

Bohr distinguished between a 'system of objects', which is postulated to be wholly independent of our observation of it, and is actually beyond the realm of possible experience, from phenomena which we do have the possibility to observe, provided we permit 'certain interactions' to take place. These interactions are between the observer and the objects (via 'means of measurement not belonging to the system'). By observing the phenomena, we necessarily lose all ability to gain knowledge about the noumenal 'system of objects'. Bohr reinforced this notion later in the paper, writing that 'it must be kept in mind that a closed system escapes all possibility of observation . . .'<sup>62</sup> Bohr's description in terms of possibility of experience or observation indicates a conceptual link with Kant's phenomena-noumena distinction.

Bohr's 'closed system of objects' bears further comparison with Kant's noumena: '[A] closed atomic system is not accessible to observation and constitutes therefore in a certain sense an *abstraction*, just as the *idea* of an isolated particle'.<sup>63</sup> Compare this with Kant's nearly identical statement that by "'noumenon" we mean a thing so far as it is *not an object of our sensible intuition*, and so abstract from our mode of intuiting it . . .'<sup>64</sup> Precisely because Bohr's closed system of objects does not admit of the possibility of referring to an object of the senses, it transgresses the limits of possible experience, just like

<sup>60</sup>This manuscript is an English translation of an extended version of Bohr's 16 September 1927 Como lecture. The manuscript is entitled 'The Quantum Postulate and the Recent Development of Atomic Theory'. All copies of the German version have been lost; this English copy is dated 12–13 October 1927, and was sent to G. C. Darwin on 16 October 1927. It is reprinted in Kalckar 1985, pp. 89–98. Large portions of this manuscript were later published in a Supplement to *Nature* 121 (1928), pp. 580–590, and then further rearranged, enlarged, and included in Bohr 1934, pp. 52–91. The excerpted portion from the manuscript corresponds loosely to the expanded version in Bohr 1934, pp. 54–55.

<sup>61</sup>Bohr, 'The Quantum Postulate', in Kalckar 1985, p. 91. Emphasis added. This excerpt should not be taken to mean that Bohr dismissed the reality of the closed systems of objects. Instead, just as Kant had done, Bohr left the closed system as real but unknowable. This point is well documented in Folse 1985, pp. 222–260; Murdoch 1987, pp. 200–222; and Daniel 1989, pp. 250–253.

<sup>62</sup>Bohr, 'The Quantum Postulate', in Kalckar 1985, p. 95.

<sup>63</sup>*Ibid.*, p. 97. Emphasis added.

<sup>64</sup>Kant 1929, p. 268 (B307).

Kant's noumena. Bohr's closed atomic systems do admit of being *thought*, as do Kant's noumena, even though nothing may be *known* of them.

Bohr's account of 'phenomena' is likewise similar to Kant's. In the passage above, Bohr claims that 'the idea of means of observation independent of the phenomena or of phenomena independent of means of observations cannot be maintained'. Again, compare with Kant: 'The objects of experience, then, are never given in themselves, but only in experience, and have no existence outside it'.<sup>65</sup> In other words, phenomena for Bohr are strictly taken to be objects of possible experience or objects of the senses, and should not be treated as objects independent of the observer. Phenomena are conditioned by the means of observation.<sup>66</sup>

Thus, intentionally or not, Bohr established a distinction between phenomena and noumena in a Kantian fashion. Phenomena are objects of possible experience, while 'closed systems of objects', like Kant's 'noumena', remain outside the domain of possible experience. The closed systems of objects are 'abstractions' or 'ideas', not things about which we can have any empirical knowledge. Bohr's emphasis upon epistemology over ontology led him to the same conclusion as Kant: closed systems of objects are real, but unknowable.<sup>67</sup>

Bohr's emphasis upon the limitations of knowledge is perhaps less surprising than often held. The division between observable and unobservable objects has been made consistently throughout the history of philosophy. Indeed, Eisler's *Wörterbuch der Philosophischen Begriffe (Dictionary of Philosophical Concepts)* from 1901 simply assumes this definition of 'phenomenon': 'appearance, i.e. something in the form of an appearance. Phenomena are the objects in so far as they are not the things in themselves, but rather their relationship is shown to be only to the knowing (experiencing and thinking) subject'.<sup>68</sup> Thus Bohr's thinking was consistent with Kant's legacy of philosophical thought in the

<sup>65</sup>*Ibid.*, p. 440 (A492/B521).

<sup>66</sup>Folse has noted that Bohr's use of the word 'phenomenon' shifted after 1939 from denoting 'the object whose properties the observation determines' to 'the whole observational interaction', although he quickly points out that this did not alter the meaning of complementarity. (Folse 1985, pp. 156–161). This shift in definition does not threaten any of the above comparisons with Kant: either way, 'phenomena' are defined in terms of possibility of experience. Bohr's definition shift in fact reflects an explicit incorporation of conceptual containment in his later writings on complementarity.

<sup>67</sup>Cf. footnote 61 for discussion of Bohr's realism.

<sup>68</sup>Eisler 1901, p. 1002. My translation: 'Phänomen: Erscheinendes, d.h. etwas in der Form der Erscheinung. Phänomene sind die Objekte insofern sie nicht das An-sich der Dinge selbst sind, sondern nur deren Beziehungen zum erkennenden (sinnlichen und denkenden) Subject darstellen.'

The Oxford English Dictionary similarly defines 'phenomenon': '1. In scientific and general use: A thing that appears, or is perceived or observed; an individual fact, occurrence, or change as perceived by any of the senses, or by the mind . . . 2. In philosophical use: That of which the senses or the mind directly takes note; an immediate object of perception (as distinguished from substance, or a thing in itself). (Opposed to NOUMENON.)' Hacking claims that this Kantian definition of 'phenomenon' is *not* the best definition of the word, and that 'had the British stuck with native masters such as Berkeley or Reid [who did not use 'phenomenon' in this Kantian sense] they would never have fallen into their own empiricist excesses'. Cf. Hacking 1983, pp. 223–224.

early twentieth century. Yet Bohr surpassed this somewhat common distinction between phenomena and noumena, incorporating Kant's own conceptual containment mechanism into complementarity.

### *Conceptual Containment in Bohr's Response to EPR*

In 1935 Albert Einstein collaborated with Boris Podolsky and Nathan Rosen on a now-famous paper entitled 'Can Quantum-Mechanical Description of Physical Reality be Considered Complete?' They attempted to prove that quantum mechanics is incomplete, and argued that it would be replaced with some new theory of nature.<sup>69</sup> The EPR paper is most famous for its proposed *gedanken*-experiment. The authors alleged that measurements of one quantum system can instantaneously attribute reality to physical quantities of two noncommuting operators of a second spatially separated quantum system.<sup>70</sup> That is, the EPR authors constructed a judgment concerning the momentum of a quantum system, as well as a judgment concerning the *simultaneous* position of the same system. Yet this is strictly forbidden by Heisenberg's uncertainty principle. Thus, within the framework of the entire argument, this negation of the uncertainty principle led to the conclusion that quantum mechanics is incomplete.

The logical steps of this argument are protracted, but following Arthur Fine, the EPR argument may be reconstructed as follows:

- I.  $[\sim U \rightarrow I] \rightarrow [I \vee U]$
- II.  $\sim I \rightarrow \sim U$
- III.  $\therefore I$

That is, if the Uncertainty principle is valid, then quantum mechanics is Incomplete.<sup>71</sup>

Bohr's first response to the EPR criticism emerged five months later, in a paper by the same title.<sup>72</sup> Bohr responded to EPR's claim of incompleteness, writing that quantum mechanics provides 'a rational discrimination between *essentially different experimental arrangements and procedures*, which are suited *either* for an unambiguous use of the idea of space location, *or* for a legitimate application of the conservation theorem of momentum'.<sup>73</sup> That is, EPR's two judgments about the quantum system can only be constructed under *different* 'experimental arrangements and procedures', so that they may *not* be combined under the guise of superseding the uncertainty principle.

<sup>69</sup>Einstein, Podolsky, Rosen 1935, pp. 777–780. Cf., e.g., Hooker 1972, Rosen 1979, Fine 1986, and Delte and Guy 1990.

<sup>70</sup>E.g. Einstein, Podolsky, Rosen 1935, p. 779.

<sup>71</sup>Cf. Fine 1986, p. 32. I have replaced Fine's abbreviation of (NSV), meaning 'Noncommuting operators cannot have simultaneously Sharp Values', simply with *U*.

<sup>72</sup>Bohr 1935, pp. 696–702.

<sup>73</sup>*Ibid.*, p. 699. Emphasis added.

Furthermore, the two sets of experimental arrangements and procedures are themselves *mutually exclusive*, so that EPR's hypothetical simultaneous momentum and position measurements are beyond the realm of possible experience.

In other words, Bohr argued that it is not enough to associate the 'elements of physical reality' solely with observables such as position and momentum.<sup>74</sup> To do so would mean forming judgments relating *uncontained concepts*. Bohr maintained that information regarding the real physical experimental arrangements and procedures, which is to say the conditions and limitations under which each individual judgment is made, *must* be included in order to guarantee that our physical judgments will be valid. Compare this with Kant's mechanism of conceptual containment: we must 'add to the concept of the subject of a judgment the limitation under which the judgment is made'.<sup>75</sup>

Seen in this light, the EPR authors were guilty of 'arbitrarily picking out . . . different elements of physical reality at the cost of . . . other such elements'.<sup>76</sup> The seemingly paradoxical situation described in the EPR argument was not meaningful to Bohr, because the authors failed to demonstrate the objective reality of their simultaneous judgments. The physical judgments in the EPR argument were not conceptually contained. In fact, because the conditions for each judgment are mutually exclusive, the simultaneous judgments are beyond the domain of possible experience. On this basis, Bohr would ultimately dismiss the argument years later: 'The whole idea is absolutely nothing when one gets into it'.<sup>77</sup> Or, as Kant has written, 'as soon as we withdraw the above condition, namely, its limitation to possible experience', the judgment becomes 'nothing at all'.<sup>78</sup>

Bohr further discussed the mechanism of conceptual containment in a 1957 manuscript:

[I]t is therefore only proper for practical reasons as well as epistemological reasons to include the observations themselves in the definition of the phenomena. Above all, we obtain by such definition a description which involves no reference to the observing subject. Indeed, in the account of experiments, we need not say that we have prepared or measured something, but only that under certain conditions certain measurable effects open to observation and reproduction by anybody have been obtained.<sup>79</sup>

<sup>74</sup>*Ibid.*, p. 699.

<sup>75</sup>Kant 1929, p. 72 (A27/B43). Cf. Hooker 1972, p. 168.

<sup>76</sup>Bohr 1935, p. 699.

<sup>77</sup>Interview 1962, p. 11.

<sup>78</sup>Kant 1929, p. 72 (A28/B44).

<sup>79</sup>From 'Position and Terminology in Atomic Physics', a manuscript dated 11 March 1957, p. 2, paragraph 7. *Niels Bohr Archive: Bohr Manuscript*, reel 22; copies in AHQP-AIP. Emphasis added. This excerpt represents Bohr's post-1939 definition of 'phenomena', more in keeping with conceptual containment. Cf. footnote 66.

By including the conditions and limitations within the concept itself, judgments concerning the contained concepts remain universally or objectively real. The real physical 'effects' are 'open to . . . anybody'.

Thus, there is a distinct Kantian flavor to complementarity: Bohr employed a two-faculty epistemology, a distinction between phenomena and noumena in terms of possible experience, and the mechanism of conceptual containment. Moreover, Bohr made frequent use of Kantian language. And yet, we have little or no evidence that Bohr ever read Kant. How are we to explain the presence of philosophical similarities and almost overtly Kantian language in the work of a scientist who apparently never read Kant? The answer appears to rest with the influence of Bohr's lifelong teacher and friend, Harald Høffding.

### Historical Influences: Høffding and Bohr

#### *Høffding as an Influence upon Bohr*

Bohr's close relationship with Harald Høffding has been described in detail by Gerald Holton, Ruth Moore, and Jan Faye.<sup>80</sup> Bohr first came in contact with Harald Høffding through his father, Christian Bohr. The elder Bohr, a professor of physiology at the University of Copenhagen, used to conduct informal philosophical discussions in his home with other professors, including the physicist C. Christiansen and philosopher Harald Høffding. Niels and his brother Harald 'were admitted as silent listeners to philosophical conversations of their father and his friends'.<sup>81</sup> Later, during Bohr's first year of study at the University of Copenhagen, beginning in autumn of 1903, he attended Høffding's lectures on philosophy.<sup>82</sup> Høffding's lectures covered 'the main systems of philosophy from the sixteenth century to the eighteenth'.<sup>83</sup> Bohr explained that 'I took a great interest in philosophy in the years after my [high school] student examination. I came especially in close connection with Høffding'.<sup>84</sup>

Høffding's friendship with Bohr extended well beyond the relationship between student and teacher. While still a student of Høffding's, Bohr corrected a mistake in Høffding's upcoming 1906 edition of a textbook on logic, and Høffding asked him to read through the entire manuscript before publication.<sup>85</sup> Following Bohr's student years, the two men remained close.

<sup>80</sup>Cf. Holton 1988, pp. 126–128; Moore 1966, pp. 14–17; Faye 1979, pp. 37–72; Murdoch 1987, p. 229; and Folse 1985, pp. 44–47. Høffding's influence on Bohr's pre-1925 scientific work has been examined by M. Norton Wise in Wise 1987, pp. 406–420.

<sup>81</sup>Léon Rosenfeld, 'Biographical Sketch' in Nielsen 1972, p. xx. Cf. Moore 1966, pp. 9–10; and Holton 1988, p. 127.

<sup>82</sup>Nielsen 1972, p. 3.

<sup>83</sup>Moore 1966, pp. 14–15.

<sup>84</sup>Interview 1962, p. 1.

<sup>85</sup>Nielsen 1972, p. 3. Cf. Interview 1962, p. 1.

Høffding took a great interest in Bohr's complementarity, and Bohr often met with him to read and discuss poetry.<sup>86</sup> As a symbol of Bohr's high esteem for the Danish philosopher, he hung a portrait of Høffding in his Carlsberg House of Honor next to a portrait of his father.<sup>87</sup>

In his lifetime, Bohr mentioned only two philosophical influences: William James and Harald Høffding.<sup>88</sup> Apparently Høffding was the source of most of Bohr's exposure to philosophical texts, rather than the texts themselves. For example, when questioned by Aage Petersen about Berkeley, Bohr responded: 'I knew what views Berkeley had. I had seen a little in Høffding's writings . . .'<sup>89</sup> It seems likely that Bohr also encountered Kant this way. According to Murdoch, Høffding was 'something of a Kant scholar, and sympathetic to neo-Kantianism'. Murdoch suggests that the 'source of the Kantian overtones of some of Bohr's statements' is actually Harald Høffding.<sup>90</sup> Thus, the reason why Bohr incorporated several Kantian aspects in complementarity while excluding others may well be that he received Kant's philosophy through the filter of Harald Høffding.

#### *Høffding's Texts: History of Modern Philosophy (1894) and Brief History of Modern Philosophy (1904)*

Høffding's two-volume work entitled *History of Modern Philosophy* first appeared in the Danish edition in 1894–95.<sup>91</sup> The books present 'a sketch of the history of philosophy from the close of the Renaissance to our own day',<sup>92</sup> and most likely served as the basis of the lectures which Bohr attended during the year 1903–4. In the second volume, Høffding devoted all of Book VII (one hundred and ten pages) to a discussion of Kant. He began his analysis of the *Critique of Pure Reason* by writing that one might focus upon any of several

<sup>86</sup>Interview 1962, p. 7, pp. 13–14. Høffding expressed this interest in several of his letters to the French philosopher Emile Meyerson. Cf. Brandt, *et al.*, 1939, p. 131, p. 156, pp. 172–173.

<sup>87</sup>Moore 1966, p. 432.

<sup>88</sup>Holton argues that Bohr's interest in James most likely came from Høffding: '[I]t is unlikely that any interested student of Høffding's will have failed to encounter some aspects of William James' work.' (Holton 1988, p. 128.) Indeed, the final chapter of Høffding's *Modern Philosophers* is dedicated to James, in which he wrote: 'James is one of the most distinguished of contemporary thinkers. He combines comprehensive knowledge with great capacity of observation, keen criticism with idealistic enthusiasm, impartiality with earnest conviction. His best-known work is *Principles of Psychology* . . .' (Høffding 1915, p. 208). Recall that Bohr mentioned having read directly from James' *Principles* in the 1962 Interview. The 1915 edition of *Modern Philosophers* is the authorized English translation of lectures delivered by Høffding at the University of Copenhagen during 1902. Cf. footnote 49.

<sup>89</sup>Interview 1962, p. 6.

<sup>90</sup>Murdoch 1987, p. 229.

<sup>91</sup>Høffding 1915, p. v. In the Preface to *Modern Philosophers*, Høffding discussed the two-volume *History of Modern Philosophy*.

<sup>92</sup>Høffding 1908, p. iii. This 1908 edition is the authorized English translation of Høffding's 1894 *History of Modern Philosophy*. All subsequent references to the *History of Modern Philosophy* will be to the second volume of the text.

different facets of the book. For example, 'prominence might be given . . . to the claim of the faculty of reason to arrive at knowledge without the help of experience', meaning Kant's *a prioriism*. Or prominence might go instead to 'the restriction of the validity of this knowledge to the empirical world', meaning Kant's limitation of knowledge of phenomena.<sup>93</sup> In other words, Høffding presented Kant's philosophy as *separable*: some philosophical aspects may be emphasized while others downplayed or ignored.

Høffding's own characterization of Kant repeatedly emphasized the limitation theme of Kant's philosophy, while ignoring or rejecting Kant's *a prioriism*. Høffding's description of Kant's 1770 Dissertation, in which Kant first proposed that *a priori* forms of intuition are space and time, did not even mention *a prioriism*. Similarly, his explanation of Kant's forms of intuition and categories ignored the *a priori* nature of Kant's formulation.<sup>94</sup> When he did mention Kant's attempt to 'establish *a priori* a complete list of categories', Høffding wrote that Kant's 'idea of synthesis in general as the fundamental form of the activity of consciousness' was '[f]ar more important than this attempt at systematisation'.<sup>95</sup> Further in his discussion, Høffding criticized Kant's quest to enumerate the number and kind of the *a priori* categories as a remnant of his earlier dogmatism:

For the analytic method employed by Kant cannot guarantee completeness; we can never be perfectly certain that all the forms have been discovered. Neither can we feel sure that the forms we have discovered are the most fundamental. The forms are the constant element in experience, and from this constancy Kant argues that it must be the faculty of knowledge which is active. But this is, and will always remain, nothing more than an hypothesis.<sup>96</sup>

Høffding concluded his discussion of Kant's 'Objective Deduction' of the categories by writing that 'Instead of being content with the significance of forms as types, patterns, and anticipations, he attempted to provide a necessary proof of their applicability to reality — and *in this he did not succeed*'.<sup>97</sup> Høffding left no doubt as to his position: 'Kant . . . believed himself able to

<sup>93</sup>Høffding 1908, p. 29.

<sup>94</sup>Høffding 1908, pp. 47–48, 52–55. Høffding's treatment of Kant in his 1904 text, entitled *Brief History of Modern Philosophy*, likewise ignored *a prioriism* in a characterization of Kant's 'whole philosophy': 'Kant maintains a sharp antithesis between the world of experience and things-in-themselves both in his theory of knowledge and in his ethics. *In fact, his whole philosophy is characterized by these sharp antitheses.*' This is from the English translation of the text: Høffding 1919, p. 159. Emphasis added.

<sup>95</sup>Høffding 1908, p. 48.

<sup>96</sup>Høffding 1908, p. 51.

<sup>97</sup>*Ibid.*, p. 58. Emphasis added.

bring forward an *a priori* proof of the fundamental principles which condition experience. As already mentioned he was not successful in this attempt'.<sup>98</sup>

Nonetheless, while ultimately rejecting *a priorism*, yet Høffding praised Kant for the limitation of knowledge to possible experience. Høffding separated these two aspects of Kant's philosophy, accepting the phenomena–noumena distinction and conceptual containment but not *a priorism*. He wrote that 'Kant goes on to show that knowledge is bound up with experience, and that this search after unity, when it ventures beyond the limits of experience, becomes involved in contradictions; at any rate it can adduce no proof of the validity of its results'.<sup>99</sup> Høffding's rejection of *a priorism* did not, therefore, extend to Kant's philosophy in general. On the contrary, he saw it as a minor flaw in an otherwise great philosophical system:

Nevertheless we have in this book [the *Critique of Pure Reason*] an immortal masterpiece of philosophy; a work which stands as a mile–stone in the long wanderings of human thought. Through his researches into the innermost nature of knowledge, Kant succeeded in discovering the conditions on which it rests; also the *limits beyond which it cannot pass*. He shows us at once the grandeur and the limitation of thought. His faith in reason was not weakened by this limitation; for the barriers arise out of the very nature of reason itself, and are known according to reason's own laws.<sup>100</sup>

Thus, Kant's true contributions to philosophy come from his recognition of the limits of empirical knowledge: there are objects which exist, but about which we can know nothing. Høffding reiterated that the phenomena–noumena distinction, 'which originated with Plato', received 'a fresh confirmation' from Kant's work.<sup>101</sup>

Høffding carried this characterization of Kant further in this 1904 text entitled *Brief History of Modern Philosophy*. Bohr worked closely with Høffding on his 1906 textbook of logic, so it is probable that Bohr was well acquainted with *Brief History* soon before or after its publication. In this book, Høffding summarized Kant's forms of intuition and categories in terms of their role in unifying or synthesizing knowledge, and *not* in terms of their *a priori* status.<sup>102</sup> Instead Høffding wrote about the 'analysis of the conditions of

<sup>98</sup>*Ibid.*, p. 69. Cf. Faye 1979, p. 44. Høffding's strong anti-*a priorism* sentiment is also related in several letters to Meyerson. For example, on 22 December 1927, he wrote that a certain philosopher 'is always under the influence of the rigid categories of Kant . . . He is too frightened of his fixed schematism. But the categories of science are born and die, and it is of large interest to follow and comprehend this movement.' My translation; the letter is reprinted in Brandt, et al., pp. 146–147: '[il] est toujours sous l'influence des catégories rigides de Kant . . . Il a trop peur pour son schématisme fixe. Mais les catégories de la science naissent et meurent, et il est d'un grand intérêt de suivre et de comprendre ce mouvement.'

<sup>99</sup>Høffding 1908, p. 31.

<sup>100</sup>*Ibid.*, p. 37. Emphasis added.

<sup>101</sup>*Ibid.*, p. 46.

<sup>102</sup>Høffding 1919, pp. 142–146.

experience', adding that 'the demonstration of the real validity of abstract knowledge (of pure reason) is closely related to the limitation of this validity'.<sup>103</sup> This led to Høffding's synopsis of Kant's conceptual containment mechanism: 'Kant proves the impossibility of constructing a science of "Ideas" . . . by the fact that ideas *contain none of the conditions of experience*'.<sup>104</sup> Thus, Høffding provided a brief paraphrase of Kant's conceptual containment mechanism, and showed that it is related to Kant's overall limitation theme.

Bohr's incorporation of specific aspects of Kantian philosophy and his rejection of others now becomes clear. Much as William James did in his *Principles of Philosophy*, Høffding's texts consistently presented Kant's philosophy as composed of separable aspects. With James, Høffding flatly rejected *a priorism*. Yet he lavished praise upon the limitation theme of Kant's philosophy: the phenomena–noumena distinction received 'a fresh confirmation', and the conceptual containment mechanism adequately resolved the paradoxes of metaphysics. Bohr absorbed these Kantian aspects, as well as a rejection of *a priorism*, from Høffding's textbooks and lectures. Thus, Høffding was the critical source of exposure to Kantianism for Bohr.

### Conclusions

Despite denials among analysts of Bohr's complementarity of similarities with Kantian philosophy, there remain several essential connections between the two. Following the pattern established by his sources of exposure to Kant's writings, Bohr treated Kant's philosophy as separable. With James and Høffding, Bohr rejected Kant's *a priorism*: Bohr did *not* agree that our conceptual framework is necessary and immutable. Yet our analysis must not rest simply with Bohr's rejection of *a priorism*, for his work did parallel several other aspects of Kant's philosophy. Notable among these shared aspects are a two-faculty epistemology, a distinction between knowable and unknowable objects in terms of the possibility of experience, and the mechanism of conceptual containment used to guarantee objective reality of judgments. Furthermore, Bohr, who was notorious for his meticulous choice of terminology, often used language that reflected these shared Kantian aspects. For example, he wrote about 'forms of perception', and described the quantum realm in terms of 'phenomena'. Consciously or not, Bohr chose Kantian language to express his fundamental beliefs.

The roots of these Kantian aspects of complementarity may be found in William James and Harald Høffding. In James' writings, Bohr was exposed to a rejection of *a priorism*, together with a 'no comment', concerning other

<sup>103</sup>*Ibid.*, pp. 148–149.

<sup>104</sup>*Ibid.*, p. 150. Emphasis added.

aspects of Kant's philosophy. James neither accepted nor denied those parts of Kant's writings that dealt with 'the possibility of knowledge *überhaupt*'. Harald Høffding, Bohr's lifelong friend and mentor, corroborated James' dismissal of Kant's *a priorism*. Yet Høffding contrasted this with explicit and extended praise for the limitation theme of Kant's philosophy, which brought to the *Critique of Pure Reason* the prestige of 'an immortal masterpiece of philosophy'.

This treatment of the roots of Bohr's complementarity illustrates a necessary distinction between philosophical aspects and historical influences. While this paper has demonstrated significant similarities between the philosophies of Bohr and Kant, we still have little evidence of a direct causal connection between the two: it appears most likely that Bohr never read Kant.

In this vein, David Favrholt responds to Jan Faye's analysis of Høffding's influence upon Bohr by writing that one can never hope to verify direct causal links within the history and philosophy of science. Even given the close relationship between Bohr and Høffding, for example, Favrholt concludes: 'It would be of interest to the history of science if it could be proved that a certain line of thought which was a *conditio sine qua non* for Bohr's conception of complementarity, was inherited from Høffding'. Yet, despite the inherent interest, such a causal explanation 'cannot be proved'.<sup>105</sup> In other words, one can never substantiate the claim that Bohr's work would have followed a different course if he had not known Høffding. Such exclusive cause-effect analyses conflate aspects and influences.

M. Norton Wise provides a far better solution. He does not 'imply the thesis that Høffding's ideas were the cause of Bohr's', but rather writes that 'Bohr participated in an environment that gave meaning and support to ideas that Høffding expressed in particularly lucid form'.<sup>106</sup> Wise and Crosbie Smith construct their mammoth biography of Sir William Thomson along similar lines. They do not argue that 'Thomson's social context determined the content of his science'. Instead, they show 'that he drew extensively on conceptual and material resources available in his industrial culture and, with motivations structured by that culture, arrived at rational explanations of physical phenomena and at means of controlling those phenomena'. In other words, '[T]he science Thomson produced was *inseparably integrated* with the industrial culture that he represented'.<sup>107</sup> In this way, the roots of Bohr's scientific and philosophical work may be understood in the context of the cultural climate in which he lived and with which he interacted. The particular environment in which Bohr participated was permeated by certain specific

<sup>105</sup>Favrholt 1979, p. 77.

<sup>106</sup>Wise 1987, p. 406. Emphasis added.

<sup>107</sup>Smith and Wise 1989, pp. xx-xxi. Emphasis added.

features of Kant's philosophy, to the exclusion of other aspects that had received equal attention from Kant himself. These specific features were thus reflected in Bohr's own writings. Bohr never had to read Kant himself in order to be influenced by his work.

This analysis of the roots of complementarity helps us to understand why Bohr has remained so enigmatic in the history of modern science. As Wise points out: 'Niels Bohr is regarded by many as a heroic visionary of twentieth-century physics, by some as an obfuscating mystic'.<sup>108</sup> Bohr's distinctive approach to quantum physics was indeed 'inseparably integrated' with his Danish intellectual environment and culture. This culture did not always translate well into other settings. Thus, even physicists who worked directly with Bohr often enlisted complementarity in support of widely divergent interpretations of quantum mechanics.<sup>109</sup> Just as Einstein remarked 'Every philosopher has precisely his own Kant',<sup>110</sup> so nearly every physicist has his own Bohr. Each re-translates Bohr into his or her own intellectual environment.

*Note added in proof:* Jan Faye treats the Bohr-Høffding relationship in greater detail in his new book (*Niels Bohr: His Heritage and Legacy*), published after the completion of this paper.

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<sup>108</sup>Wise 1987, p. 411.

<sup>109</sup>For example, John Wheeler has supported the many-worlds thesis, which attempts to remove the restriction of knowledge to possible experience by radically restructuring Bohr's ontology. This interpretation shares very little in common with Bohr's complementarity. Cf. Stapp 1972, pp. 1101-1102, and Gribbin 1984, pp. 235-254 for a description of the many-worlds thesis.

<sup>110</sup>Quoted in Miller 1984, p. 125. Perhaps more revealing is Einstein's comment that 'Kant is a sort of highway with lots and lots of milestones. Then all the little dogs come and each deposits his contribution at the milestones.' Quoted in Rosenthal-Schneider 1980, p. 90

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