This is a pre-print of an article published in Review of Philosophy and Psychology, Vol. 11, pp. 977–994, 2020. Please used the published version here to cite this article.

A Psychological Approach to Causal Understanding and the Temporal Asymmetry

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Abstract

This article provides a conceptual account of causal understanding by connecting current psychological research on time and causality with philosophical debates on the causal asymmetry. I argue that causal relations are viewed as asymmetric because they are understood in temporal terms. I investigate evidence from causal learning and reasoning in both children and adults: causal perception, the temporal priority principle, and the use of temporal cues for causal inference. While this account does not suffice for correct inferences of causal structure, I show it to serve as a preliminary understanding of causal concepts as asymmetric, that later incorporates other types of evidence (leading up to difference-making, or causal processes). This approach supplies causal models with an asymmetric concept of causation that underlies hypotheses about causal structure, as I will illustrate from the framework of the knowledge-based causal induction model. I further argue for an integrating perspective, showing how the understanding of causes as preceding their effects underlies both psychological models and philosophical debates over time and the causal asymmetry, particularly regarding problem cases such as simultaneous causation or backwards causation, and the conceptual connection between causation and action.

1. Introduction

A distinctive feature of causal relations is their asymmetric character: causes bring about their effects, while effects do not bring about their causes. Within the metaphysics of causation several types of asymmetries have been investigated corresponding to various kinds of dependence including the direction of time, counterfactual dependence, processes, agency. In epistemic context, the causal asymmetry plays out at an explanatory level – while one can infer causes from effects and effects from causes, only causes explain their effects. Since these uses presuppose an understanding of the asymmetric character of causality, the question is how people understand the causal asymmetry in the first place. In providing an answer from a conceptual or phenomenological perspective, I argue that the causal asymmetry is understood in temporal terms, drawing from recent findings in experimental psychology, particularly on causal reasoning and causal learning in children and adults. In so doing, this paper also attempts to bridge philosophical and psychological

research on causality, by disclosing how the ordinary understanding of causal concepts in temporal terms underlies philosophical considerations on different causal concepts and cues to causality.

My approach is to investigate causal reasoning and the usage of causal concepts, with emphasis on the weight attributed to evidence from temporal priority. While my analysis of people's understanding of the causal asymmetry is philosophical, in psychological context it fits under the knowledge-based induction model of causal learning (Waldmann 1996, Lagnado et al. 2007). Under the assumption that people learn causal structures on the basis of hypothetical knowledge, which in turn can be obtained through temporal order information, I argue that the concepts of causation at use in these hypothetical models already have the asymmetric feature embedded via temporal succession. While witnessing an event occurring after another is not a sufficient condition for the former to cause the latter, it leads up to hypothesizing a causal connection. This process incorporates a preliminary understanding of causality. Other types of evidence that strengthen the inference, especially difference-making information, are later on incorporated within causal thought. I further argue that this conceptual picture is present in the causal thought of children over 3 years of age, as shown in children's causal perception and early usage of temporal information, the use of the temporal priority principle, inferring causal structure through temporal cues, and subsequent integration of distinct types of evidence. I conclude by placing the psychological findings in philosophical context, namely explaining how the ordinary understanding of causation reflects the connection to temporal succession, and how, in turn, this understanding underlies debates on causal concepts both within metaphysics and scientific domains. While my approach does not address the nature of causality and time, it contributes to addressing questions at the intersection between the metaphysics of causation and the psychology of causal inference, such as how the connection between time and causal understanding affects the understanding of more complex instances of causality (e.g., simultaneous causation, or backwards causation).

In the context of current philosophical and psychological research on causality my approach addresses a question that causal models, which are increasingly popular in both the psychology of causal inference as well as in philosophical investigations of causation, leave unanswered. From a philosophical perspective, causal models do not provide a non-circular analysis of causality, i.e., they already rely on a previous concept of causality. An illustration of this is Woodward's (2003) interventionist approach and its application in psychological context (Woodward 2007): while causal models capture important aspects of causal judgment – in Woodward's theory, evidence from interventions - the nature of the causal concepts at use in constructing the models is not specified. My aim is to approach this question from a perspective focusing on the asymmetry of

causation. As causal models are built on an assumption of causal connections being asymmetric, the question is where can this asymmetry be traced. Since my answer emphasizes temporal succession, my approach excludes other cues associated with the causal asymmetry in the philosophy of causation, particularly intervention or action, as being constitutive of the preliminary understanding of causality.[1] Instead, on the view defended here, these cues are used to infer causally once a more advanced level of causal understanding is achieved. While further work is needed on agency, intervention, counterfactuals, and perhaps other cues to causality, the current paper explores psychological evidence that the causal asymmetry is understood in temporal terms, disclosing the implicit understanding on which causal concepts are based before they are connected to other concepts or dependencies. The advantage of this view lies in its integration of the role of temporal order information across the ordinary understanding of causation, psychological models of causal reasoning, and the philosophy of causation: the early connection between time and causality shapes how the other cues to causation or causal concepts are used. Regarding the developmental dimension of my investigation, one thing to clarify is that my claim that people possess a preliminary understanding of causation as asymmetric on the basis of temporal succession need not entail that the concept of causality originates in the experience of time. Several other developmental hypotheses are compatible with the understanding of causality I propose, as will be discussed in section 3. Regardless of the origin of causal concepts, my claim that the causal asymmetry is understood in temporal terms before other cues to causation, which play different roles in causal inference, would still stand.

I rely on a set of distinctions from the philosophy of causation to articulate my account of causal understanding, and to explore its use in psychological context. Firstly, there is Godfrey-Smith's (2010) distinction between different concepts of causation focusing on several features of the world. As my investigation is conceptual, rather than focusing on the features of the world, I discuss the capacities that enable people to understand causality as asymmetric. I argue that people think of causality as asymmetric as a result of their capacity of following temporal sequence, which they employ to make sense of the causal relations as witnessed in the world. These distinctions between the experienced causal connections and the psychological capacities enabling causal reasoning explain why people think of causal relations as asymmetric even if the universe may be

1 In relation to Woodward's account, my view can be seen in opposition to Gijsbers and de Bruin (2014) who argue for an agency concept of causation to address the issue of circularity: while Gijsbers and de Bruin recognize the importance of temporal information but do not deem this kind of understanding causal, I argue that prior to incorporation in models of causal inference causal concepts are primarily understood in temporal terms. Two caveats here are that my view targets causal models more broadly, not solely interventionism, and that I do not make a definite developmental claim.

symmetric (see Price 2007, and Loew 2017).[2] Thus, another way of spelling out the motivation of this paper is to explain why people think of causal concepts as asymmetric, even under the assumption of a symmetric structure of the world.[3]

Secondly, Hall's (2004) distinction between causation as production and dependence, further adopted in psychological setting by Waldmann and Mayrhofer (2016) helps connect the use of different kinds of evidence to corresponding causal concepts. Briefly put, the production concept of causation focuses on what connects the causal relata, what is transferred from causes to their effects, while the dependence concept emphasizes the status of causes as difference-makers to their effects. Whereas the production concept incorporates spatio-temporal information, my approach is not necessarily committed to this concept. As argued below, temporal order information can be complemented with further information about either a process/mechanism or difference-making. This way of distinguishing between different types of evidence corresponding to the different concepts of causation helps in articulating distinct steps in the development of causal thought.

2. The causal asymmetry and temporal succession: a model

I defend the view that people's understanding of causal concepts embeds information about the experienced temporal order, resulting in causality being experienced as asymmetric. This structure, which can be traced in psychological studies of causal reasoning, also underlies philosophical approaches to the causal asymmetry.

There are two ways of spelling out a model of causal understanding where the causal asymmetry follows the direction of time. The model would hold that a claim such as 'X causes Y' implies that:

i. X is temporally prior to Y.
ii. Y is not temporally prior to X.

The stronger claim is (i), which entails (ii), but, notably, excludes cases of simultaneous causation. As I defend a version of (i), I will discuss this apparent shortcoming in more detail. To begin with, from the psychological perspective pursued here, there are two reasons to opt for (i). Firstly, since (i) implies (ii), it enables both direct and indirect ways of inferring causal structure. Directly, if Y follows X, Y can be judged to be X's effect. Indirectly, events succeeding the effect can be ruled out from the list of possible causes. While (ii) only captures indirect uses, (i) can account for both.

2 In particular, Loew makes the case for the use of local asymmetric models in causal explanation in contrast to the laws of physics.

3 This question, thus, avoids the clash between realist and projectivist views, by narrowing down the scope to how the causal reasoners understand the asymmetry. Whether this corresponds to a feature of causality in the world (say, the metaphysics of time and causation) is a separate issue.

Secondly, (i) requires a simpler conceptual kit, as it accommodates instances of causal learning through witnessing instances of succession between X and Y.[4] In this version, the connection between causal and temporal relations is easier to comprehend for the causal learner, as it only requires the experience of succession. Formulation (ii) would require operating with additional relations – either negation (X does not follow Y) or disjunction (Y follows X or Y occurs at the same time as X). In either case, (ii) would need a more complex reasoning process in addition to keeping track of temporal order.

To make this into a more general point, with Humean overtones (as in Hume 1748), the experience of succession often leads to conjecturing a causal connection between X and Y. However, a notable concern is the possible conflation between causal relations and joint effects: temporal order is not a sufficient condition for X and Y to be causally connected; they may be randomly correlated, or they may be results of a common cause. This objection can be answered by employing a more complex set of conditions and tests for identifying causal relations, and my claim is that temporal order is a necessary condition for awareness of one particular feature of causal relations: their asymmetric character. I take this to constitute a preliminary concept of causation causal reasoners use: the embedded temporal order provides the asymmetry, but other components, leading up to a complete account of difference-making, or of a process, which would rule out joint effects, are lacking. The complete usage of causal concepts is present in adult causal reasoning.

Since I previously mentioned that my model relies on temporal direction while excluding other cues to causality as candidates for the causal asymmetry, I will explain how this works in the case of action with the possibility of extending this point to other cues. Claims (i) and (ii) above also apply to judgments such as ‘Doing X brings about Y’. Particularly, through (ii) actions are constrained by a temporal frame: one cannot act to undo a previously brought about effect. Similarly with the discussion above, actions can have simultaneous effects, but as this model is not meant to provide sufficient conditions, it can hold for an understanding of actions as typically followed by outcomes. This falls in line with the discussion above – while action is an important cue to causality, what can be acted on is constrained by the temporal order. It should be noted that this holds for the interventionist framework or analogous models, but also for less complex ways of inferring causation through action.

Before expanding on the psychological background, more clarifications on the relation to the philosophical debate are required. The two issues mentioned above, simultaneous causation and joint effects are commonly counted as counterexamples to the metaphysical view equating the

4 As mentioned above, for this reason, my view here can be roughly labeled as Humean. This applies to the temporal account for the causal asymmetry, but not to patterns of association, as I am relying on causal models instead.

causal and temporal asymmetries.[5] The model for the relation between the causal asymmetry and temporal order proposed above applies to causal concepts. While my investigation focuses on the psychological context, this conceptual model can be extended to explain more general aspects of causal understanding. The point to stress here is that while considering metaphysical questions, my claim concerns causality understood by the causal reasoner, and not causality in the world. Insofar as I will be considering aspects of the metaphysical debate, the remarks should be seen from a metaphilosophical perspective – how underlying assumptions about causal concepts shape the said debates, rather than as making claims about causal relations as such. Nevertheless, the correspondence between causal concepts in psychology and philosophy can be explained from a broader perspective on causal understanding and the underlying assumption that causes precede their effects captured by this model. This is a discussion for section 4.

In a broader psychological context, the distinction between two steps in causal understanding, with a preliminary concept of causation incorporating the causal asymmetry understood in temporal terms works within the knowledge-based causal induction model. This model holds that learning about causal structure presupposes preliminary knowledge: 'causal-model theory is based on the assumption that causal induction cannot solely be based on the processing of statistical information. Additional top-down assumptions, for example, about causal directionality, have to guide the processing of the learning input' (Waldmann 1996: 54). Lagnado et al. point out that hypotheses about causal structure accompany the majority of causal learning tasks: 'these hypothetical causal models guide the processing of the learning input. The basic idea behind this approach is that we rarely encounter a causal learning situation in which we do not have some intuitions about basic causal features, such as whether an event is a potential cause or effect.' (2007: 156) There are a few points to stress for my purposes here. Firstly, these hypothetical models guiding people's use of evidence from, say, statistical information, insofar as they are causal models, presuppose an understanding of the concept of causation. Secondly, as the excerpts above show, the contrast between directionality and statistical information (the latter of which is symmetric) is apparent. Thus, causal concepts at use within these hypothetical models already meet the asymmetry constraint, unknown to causal reasoners on the basis of statistical information alone. A final point, shifting back to the philosophical issue, is that there are similarities between hypothetical models and causal models for, say, intervention use. Interventions already make use of the causal asymmetry, and it, thus, appears that a preliminary understanding of causal concepts is necessary for people to infer causal structures from hypothetical models on the basis of

5 See Schaffer, section 2.2.

interventions. This issue will be explored in both psychological and philosophical context in the following sections.

Before moving on to the psychological basis of the model above, I would like to point out another link between temporal succession and the causal asymmetry. Several studies into causal and diagnostic reasoning show discrepancies between inferences from cause to effect and inferences from effect to cause. Sloman and Lagnado (2015) review evidence showing adults to be more successful at inferring effects from causes than the other way around (Fenker et al. 2005), with the same pattern holding for children (Hong et al. 2005), and that people assess the probability of effects given their causes higher than the probability of causes given their effects even when no significant difference between the two probabilities is to be expected (Tversky and Kahneman 1974). The connection to temporal order can be traced to a suggestion by Tversky and Kahneman that people are able to run mental simulations that go forward in time, while diagnostic reasoning would require a different ability. Sloman and Lagnado conclude that mental simulations require more information than probabilistic dependency, namely temporal order (as in Schwartz & Black 1999) and an understanding of the mechanism through which causes bring about their effects. While, as mentioned earlier, I do not exclusively support a geometrical-mechanical concept of causation, I emphasize once again the connection between the temporal component and the direction of causality.

3. Causal perception, causal reasoning, and the temporal asymmetry

In this section I explore evidence for the use of the model proposed above in children's and adults' causal reasoning. I take the use of temporal evidence to infer causally to mark an understanding of causation in asymmetric terms, with the causal direction following the direction of time. By investigating causal perception in younger children and the use of temporal cues in causal reasoning by pre-schoolers and adults, I conclude that the model holds for children over 3 years of age and for adults. Regarding further questions about the developmental origins of the connection between causal concepts and temporal order, and the continuity to adult causal reasoning, I contrast a hypothesis that causal concepts are built on the basis of temporal order information with two other possibilities - of the asymmetry being epistemically irreducible, and of an initially symmetric concept of causality. As this question can only be settled empirically, my main claim is that an implicit understanding of causality in temporal terms is present in adults and children older than 3 without commitment to a developmental thesis about causal concepts originating in the experience of temporal succession.

Concerning developmental investigations of causal perception, different accounts have been brought forward. For my purposes here, I focus on the role of temporal information. Leslie (1982) employs Michotte-style launching events, and based on habituation and looking times suggests that infants perceive the spatio-temporal contiguity among objects as a causal connection. This holds for both causality between objects and also when a human agent is involved. Further work by Leslie and Keeble (1987) argues that 6-months olds are able to distinguish between causal connections and sequences of events where delays are present. Oakes and Cohen (1990) raise doubts concerning whether 6-month olds perceive causality. Contra Michotte and Leslie, experiments where launching sequences involve objects as opposed to geometrical shapes show that 10-month olds, but not 6-month olds perceive launching events as causal. Moreover, while Leslie follows Michotte (1963) in suggesting that the perception of causality is modular, Cohen and Oakes (1993) further argue in favour of an information-processing model where 6-month olds are sensitive to temporal information, but do not perceive the object as a whole, and as such do not perceive the event as causal until 7-10 months (432). While the modularity of causal perception is still subject to debate (see Schlottmann 2000, Saxe and Carey 2006), for my purposes here, I stress the importance of temporal information. The launching sequences perceived by infants as causal involve temporal succession and contiguity, whether 6-month olds or 10-month olds perceive causality, their perception is connected to a temporal component. While it is important to note the physical component to causal perception, that is, the contact between the causal relata, one thing to point out is that temporal succession is present in cases of physical causality, as shown in the work described above, but also in social causality, where contact is not necessary, as studies such as Schlottmann et al. 2013 show. Thus, following temporal succession enables children to perceive instances of both physical and social causality.

Studies of causal perception in preschoolers indicate a strong connection between causal perception and temporal succession. Bullock, Gelman, and Baillargeon (1982) propose three principles guiding causal thought in children starting at 3 years of age, kept through adulthood: determinism, priority, and mechanism (211). This model is important for my investigation firstly because it argues for a stance where similar principles, particularly the priority of causes over effects, operate continuously between childhood and adulthood. Secondly, the authors single out these principles as a ‘causal theory’ through which both children and adults understand the world, and not necessarily as features of physical causality. While I discuss philosophical implications in section 4, for now I emphasize the implicit character of understanding causal priority. According to Bullock et al., causal understanding develops by ‘learning where, when, and how to apply the rules of reasoning rather than figuring out what those rules might be’ (1982: 251). More recent

investigations of temporal priority were conducted by Rankin and McCormack (2013) aiming at determining 'the age at which the inviolability of the principle is properly appreciated' (1). The experiments used a device similar to Bullock and Gelman (1979), where a jack-in-the-box popped up as a result of a ball rolling on one runway, with a ball of a different colour rolling on another runway shortly after the jack popped up. When asked which ball made the jack pop up, the children's answers would reveal whether their causal judgements matched the temporal order of the events. The 4-year olds were successful, while the 3-year olds performed above chance. The authors further attempted to explain the discrepancy between the 3 and 4-year olds through the possibility of memory playing a role in connecting causal and temporal judgements, or through the hypothesis that understanding of the temporal priority principle emerges around the age of 3. A further point relevant for my discussion concerns the comparison with the Bayesian account, which 'does not aim to describe the psychological processes involved in causal inference, therefore, as it stands, the issue of whether 3-year-olds' problems stem from memory difficulties or conceptual problems is not one that Bayesian theorists need take a stance on' (Rankin and McCormack 2013: 7-8). While the authors stress the need to further explain 3-year-olds' difficulties with the temporal priority principle, a concern which does not arise on the Bayesian view, below I extend this point to the issue of the causal asymmetry.

A further connection between children's understanding of causality and temporal succession can be noted in relation to work on temporal concepts by McCormack and Hoerl (2017), particularly, a model for the development of temporal concepts. For my purposes here, while a full-fledged concept of time is not necessary for tracing temporal order, and thus for an asymmetric concept of causality, the ability to follow temporal sequence is necessary. The model by McCormack and Hoerl attributes children younger than 24 months with representations of repeated event sequences (2017: 305). At this stage, time is event dependent, and children do not have a notion of past and future (307-308). The ability to follow sequences is important for my claim: children follow event sequences, and have expectations regarding what follows what. While not all connections of this kind are causal, this capacity incorporates the asymmetric feature of causal thought: effects follow causes. As temporal concepts develop, including the linear feature of time, and the distinction between past and future, so do causal concepts, for instance the link between the ability to change an effect through its causes but not the other way around, and the ability to change the future but not the past.

Before moving on to causal reasoning, it is time to assess to what extent this developmental evidence supports the model of causal understanding above. While the studies include temporal information, Michotte launching events in particular focus on spatio-temporal contiguity, and not

exclusively temporal order, and the Rankin and McCormack study does not draw particular conclusions about causal understanding before the age of 3 and its relation to the temporal priority principle. This leaves open several possibilities regarding whether or how the causal asymmetry is understood by children younger than 3:

a) The causal asymmetry originates in children's experience of time – according to this hypothesis, causal concepts originate in experiences of temporal order and are asymmetric. Under this view, the close connection between causal and temporal order can be explained though its developmental continuity. While the relation between cognitive development and adult causal concepts is subject to investigation (see Danks 2009), this particular hypothesis would explain the ease of the use of temporal order information through its early connection to the development of causal concepts.
b) The causal asymmetry is epistemically irreducible – children understand causal concepts as asymmetric, and may do so before connecting them to the experience of temporal order. For instance, upon discussing the role of agency in physical causality, White (2006; 2009) suggests that children may experience both the cause – pushing an object, and the effect – its resistance, and yet distinguish between a cause object and an effect object.
c) Children use causal concepts as symmetric before they connect causality to other cues such as temporal order or action, and they understand the causal asymmetry. This is also a possibility arising from White's considerations mentioned above.

Deciding between these options is an empirical question that lies beyond the purposes of this paper. Nevertheless, this would help paint a broader picture regarding the importance of temporal order and the asymmetry of causation. For instance, do people find it easier to reason causally on the basis of temporal cues because the concept of causality is built around the experience of time (a above), or because the directions of time and causality match even though they are understood separately (b), or should the answer be sought by comparing temporal order with other cues that gradually come into use, such as covariation information, counterfactuals, interventions, etc. (c)? Leaving the choice between these possibilities open, I note that they are all compatible with my model above – even if temporal order may not be at the origin of the causal asymmetry, it can connect to previous understandings of causal concepts. I am now going to explore evidence that temporal succession plays a key role in causal inference, which supports the model proposed above regardless of what developmental conclusions one may draw.

Concerning children's causal reasoning, McCormack, Frosch, Patrick, and Lagnado (2014) investigate the employment of temporal cues, probability information and interventions in causal inference. The results point to the prevalence of temporal cues among different types of evidence

used for causal inference. The experiments required participants to infer causal structures from a device formed of three components of different shapes and colours, where a rotating component would cause other components to rotate in conformity with causal chain or common cause structures. The participants could also prevent a component from rotating through the use of a 'stop' sign. In Experiment 1, participants grouped by age - 5 to 6 years old, from 6 to 7 years old, from 7 to 9 years old, and adults were presented with incongruent evidence from temporal cues and statistical information and asked to identify the causal structure. In Experiment 2 a similar question was asked, but the conflicting evidence came from temporal cues and intervention information (in this case, intervention pertained to activating each one of the variables in turn and seeing what other variables would simultaneously activate). In Experiment 3, temporal information was not available, and participants had to infer the causal structures from the statistical data about intervening to disable one variable and activating the others in turn. Children preferentially employed the temporal cues for inferring causal structures in the incongruent cases and in the last experiment, where no temporal cues were available, only adults and the older group of children performed above chance. The authors explain the findings firstly by emphasizing that statistical information is more difficult to process, and thus children mainly relied on temporal cues. Secondly, there may be an inherent tendency in children as well as in adults for using temporal information over statistical information when inferring causal structures. The authors connect this explanation to two studies by Shulz (1982) and Ahn et al. (1995) arguing that children and adults place more weight on mechanism related information than on statistical information, which suggests that the geometrical-mechanical (or production) model of causal thought may be developmentally more fundamental than the difference-making one. Since my aim is to explain how people understand the asymmetric feature of causal concepts rather than choosing among these two concepts, I emphasize the contrast between temporal cues, which set directionality, and other types of cues that are either symmetric (statistical information) or rely on a preliminary assumption of directionality (interventions, mechanisms).

Based on a similar device, Frosch et al. (2012) show that children between the age of 4 and 8 can infer causal structures on the basis of temporal cues, but do not connect the newly learned causal structure to corresponding interventions. This suggests that at this developmental stage children connect causal structures to time, but not to interventions. I take this to be an illustration of the preliminary concept of causation I propose here. While it would be difficult to attribute complete causal reasoning to participants that do not connect causation to difference-making (which, among other things, may lead to considering joint effects as causally related), a preliminary

understanding connected to time would account for children's comprehension of the asymmetric character.

Before moving on to adult causal reasoning, I will address a potential objection. One may point to results from the developmental literature on causal maps (as in Gopnik et al. 2004) to claim that the use covariation information precedes the connection between causal concepts and temporal order. For instance, in Gopnik et al. 2001 children from 2 to 4 years old identify causal connections on the basis of statistical dependencies in blicket-detector experiments. This understanding of causation is described by McCormack and Hoerl (2015) as a causal-power concept of causation, and it differs from my treatment of causation, which fits a causal-temporal concept. The issue would thus be that causation is understood through statistical dependencies before developing a connection to time. My reply is that a concept of causation as illustrated by the blicket detector experiments lacks the grounds for the causal asymmetry: statistical dependencies can go both ways, while causal relations run from causes to their effects. While this issue can be remedied through causal maps following the interventionist model (Schulz et al. 2007), there are two further issues with this. Firstly, these models are asymmetric because the graphs are designed as directed to begin with, and secondly, more importantly for my point here, it is doubtful whether young children can reason about causation in this complex manner. Results from above-mentioned work, such as Frosch et al. (2012), where children are able infer causal relations on the basis of temporal cues but do not connect them to interventions raise questions regarding children's ability to reason with interventions within a three-variable model. By contrast, investigating the relation between causal reasoning and temporal information takes into account the asymmetric feature of causal relations. Furthermore, the primacy of the usage of temporal cues over interventions or conditional probabilities shows causal concepts to be understood as asymmetric on the basis of temporal direction from earlier on. Thus, while the causal maps approaches focus on other important features of causal thought, the causal asymmetry is better captured by what McCormack and Hoerl (2017) deem causal-temporal reasoning.

Investigations of adult causal reasoning suggest that temporal cues can be connected to interventions. A study by Lagnado and Sloman (2004) shows the efficiency of causal inference based on both intervention and temporal cues. In a set of experiments of inferring causal chain or common cause structures, adult participants were more successful in both intervention as well as observation-based inferences when they were either directly intervening, or observing interventions that were followed by the effects. In the general discussion, the authors emphasize the advantage of intervention over observation in terms of ruling out confounders. They also point out that in everyday contexts interventions are prior to their effects. Thus, in this setting intervention and

temporal information come in as a package constituting the everyday concept of causation. While causal structures may be inferred by focusing on various features of causal concepts, reliable causal inference needs to consider difference-making information (to rule out confounders, or joint effects, for instance). In conjunction with the data on preferential employment of temporal cues, I take this evidence to support the usage of a preliminary understanding of causality in temporal terms. People find it easier to infer causal structures when the evidence maps on their preliminary understanding of causal concepts (i.e., in temporal terms). This can also explain the asymmetry between causal and diagnostic reasoning pointed out above: causal reasoning follows the direction of time, while diagnostic reasoning requires an inference in the reverse direction. A further study by Lagnado and Sloman (2006) on the use of statistical data, temporal cues, and interventions connects these results to the knowledge-based causal induction: 'a hypothesis-driven account of learning, whereby people use cues such as temporal order to generate initial models and then test these models against the incoming covariational data' (460). This connects to the considerations on knowledge-based causal induction above, where I claimed that these initial models use a preliminary understanding of causal concepts. In cases where hypotheses are provided by temporal information, then this preliminary understanding encompasses the direction of time.

The Lagnado and Sloman (2004) study is also relevant for dealing with another possible objection, regarding simultaneous causation: as participants were less successful in identifying the causal structures in the absence of temporal cues, simultaneous causation appears to be more difficult to accommodate for causal reasoners. Further evidence in this sense is presented in a study by Bramley, Gerstenberg, and Lagnado (2014), employing two Bayesian models of inferring causally, out of which only one allowed for simultaneous causation. The results showed participants to reason in accordance with the non-simultaneous model. This is consistent with the claim above that simultaneous causation is more difficult to grasp for causal reasoners.

Another possible objection refers to experimental results which on a first glance contradict the previous claims. What if the relation goes in the opposite direction and the use of causal concepts drives people's temporal judgements? Two studies by Bechlivanidis and Lagnado (2013; 2016) suggest that causal judgements may influence judgements about temporal sequence. While these results support the connection between causality and time, they bring into question the legitimacy of the claim that temporal order is at the origin of people's understanding of causation as asymmetric. Both studies note a 'reordering effect' - the temporal order of the events is arranged in line with the newly learned causal order (2013), or causal perception (2016). The authors interpret this as a top-down effect of causal representation: 'the causal representation influences the experienced temporal order, at the time of perception or retrieval, or alternatively it completely

overrides the need to spontaneously generate a temporal order judgement, since the order of events is implicitly represented in the causal relationship' (Bechlivanidis and Lagnado 2016: 67). For my purposes here, it is important to stress the authors' endorsement of the temporal priority principle: 'causal representation has embedded temporal order information' (67), as another link to developmental investigations. Even under the reordering effect, causal structures are assumed to be consistent with temporal order, what happens is that people assume the temporal sequence to match their causal judgements. Thus, in line with the previous claims on a preliminary connection between temporal succession and causal understanding, causal concepts are assumed to conform to temporal direction, even when that leads to mistaken judgements about time.

A final objection to consider is that by itself temporal succession provides very weak evidence of causal structure, even for the purposes of generating hypotheses: in the absence of cues such as spatiotemporal contiguity or statistical information it is difficult to see how one would distinguish between causal occurrences and events that merely succeed one another. In reply, I emphasize that I do not hold that temporal succession is used in generating hypotheses in isolation. It would be impossible to do so within everyday experience, unless one considers an idealized model; as I am interested in causal understanding my focus falls on the former, and not the latter. Thus, I acknowledge that generating causal hypotheses may involve witnessing several instances of events occurring, or spatio-temporal contiguity. While these are neither necessary nor sufficient (for instance, spatial contiguity is not necessary for social causation), according to the view defended here, it is temporal succession that plays a key role in singling out the causal structure because it is indicative of the asymmetric character. Hypothesis generation involves exposure to a kind of background that may include different types of information, but temporal order guides the choice of hypothesis, being a necessary part of the process.

To conclude this section, the claim that the causal asymmetry is understood in temporal terms, as part of a preliminary concept of causation is consistent with psychological investigations on both children's and adults' causal reasoning, and can be further connected to developmental studies on causal perception. While this evidence does not provide a decisive lead regarding the developmental origin of the causal asymmetry, it highlights the importance of temporal order information within the implicit concept of causation described above. The use of temporal information in causal inference shows that causal reasoners connect causal relations to temporal order before other features. Temporal information is traced earlier in development in comparison with other cues, such as intervention (Frosch et al. 2012), or mechanism (Scholttmann 1999). The use of temporal information in connection to intervention under the knowledge-based model also supports the claim that a preliminary, asymmetric, concept of causation is at work within

hypothetical models. This evidence supports the earlier claim that the implicit understanding of causation is connected to the temporal asymmetry, while the other asymmetries, such as that of action, rely on this understanding. Finally, psychological research also shows people to either find it more difficult to infer causal structures when cause and effect occur simultaneously, and to prefer models excluding simultaneous causation. This also falls in line with the claim that while a fully-fledged concept of causation admits simultaneous cases, the preliminary understanding only includes the cases where the temporal order is apparent. In the next section I illustrate how the conceptual considerations so far can help clarify and open new leads on the relation between time and the causal asymmetry as discussed in the metaphysics of causation.

4. An integrating perspective on causal reasoning and philosophical analysis

In this section I provide an integrating perspective on the psychological research and the philosophy of causation. I start by sketching out a framework explaining how the psychology of causation shapes assumptions about causal concepts present in causal understanding. Particularly, I argue that this understanding of causal concepts underlies philosophical investigations of the asymmetry of causation and time.

To set up a framework for connecting people's understanding of causation to philosophical investigations, I rely on R.G. Collingwood's approach to metaphysics as a study of presuppositions that render scientific inquiry possible, or 'a science of absolute presuppositions' (Collingwood 2002: 41). Unlike Collingwood's focus on history as determining the absolute presuppositions, my claim is that the origin of the preliminary concept of causation discussed above lies in how people understand causation and reason causally, and thus on my view, in this particular respect, metaphysics can draw more from psychology than from history. The preliminary understanding of causal relations following temporal order plays the role of a presupposition – it is not explicitly stated in causal talk, but it underlies how we think about causal concepts, particularly their asymmetric character. Our understanding of the causal asymmetry can be traced to the ability to follow sequences of events, and we think of the typical cases of causal connections in these terms. The problem cases such as simultaneous causation, backwards causation, or time travel depart from this understanding, and are thus more difficult to identify in everyday context, or comprehend in philosophical debate. A further analogy with Collingwood is that this way of understanding causal concepts need not be correct. While on Collingwood's view absolute presuppositions have no truth value (Collingwood 2002: 32), for my purposes here, rather than discussing truth values, I claim that this understanding of causal concepts can be applied more or less successfully when thinking about causality. This means that the problem cases mentioned above are not to be explained away in

terms of the temporal asymmetry, but rather considered illustrations of the limitations of this understanding of causation. For instance, backwards causation may be possible, but it would require a different understanding of causation.

On the view defended here, the presupposition that causal relations follow temporal order is the result of how people learn about causality, as shown in psychological research. This view on causal learning is in line with the psychological models discussed above - Waldmann's knowledge-based causal induction, the causal theory described by Bullock et al., and the approach to temporal concepts by McCormack and Hoerl. The first can accommodate temporal succession and causality in the process of hypothesis generation – while Waldmann refers to previous knowledge, I have argued that temporal sequence is an important source of such knowledge. The second presupposes a connection between temporal succession and causality used in articulating a principle for understanding causality. The last explains how succession is present from the early stages of temporal understanding. The connections can be explained as follows:

- Knowledge-based causal induction (Waldmann): temporal succession is an important source of hypotheses regarding causal structure, which can be tested by various means. While causal order is different from temporal order, temporal order is already presupposed by hypothetical causal models built on the basis of temporal information. Furthermore, the ability to generate hypotheses on the basis of temporal sequence is an indicator that the causal concepts at use are connected to temporal information. The knowledge-based model can also accommodate concepts of causation connected to other cues, but for my purposes here I emphasize its compatibility with my account above.[6]
- The priority principle (Bullock et al.): temporal succession is captured by the priority principle that is part of causal understanding starting at 3 years of age and continuing through adulthood. While other principles, such as determinism and mechanism are included, temporal succession accounts for causation being understood as asymmetric.
- McCormack and Hoerl 2017: while not discussing causality, the authors propose an event-dependent understanding of time, starting with repeated event sequences in children younger than 24 months. This can provide developmental support for causal understanding as described above.

Regarding how this presupposition underlies the philosophy of causation, I focus on the analysis of the the causal asymmetry in temporal terms. Notably, there are cases that pose problems

6 Though a further question would arise regarding the extent to which these various possibilities would account for the direction of causality – counterfactuals, for instance, could go both ways as shown in the cases of causal and diagnostic reasoning. Nevertheless it is also possible that if the causal asymmetry is epistemically irreducible, such intuitive understanding would be the source of hypotheses.

for attempts to equate the causal and temporal asymmetries: simultaneous causation, backwards causation, time travel (see Schaffer 2016: 2.2 for an overview). To be clear, in analysing these cases, I do not make any claims about their existence (say, whether there are instances of backwards causation), but provide a framework for understanding them. The conceptual and the metaphysical can be fully independent – there can be backwards causation without anyone conceptualizing it; equally, people can have a concept of backwards causation without there being any causal occurrences of the sort.[7] In this sense, simultaneous causation is more important to explain since it can be witnessed in everyday instances. I hold that both the ordinary understanding of such cases, as well as the philosophical discussion, rely on the assumption that causes precede their effects. Causal reasoners start by understanding causation as following the direction of time and as more conceptual connections are constructed, the concept of causation can be enriched such as to capture cases that do not follow the arrow of time, but can be singled out as causal through other tests. Thus, concepts such as simultaneous causation, backwards causation, or time travel can be seen as results of removing the previous scaffolding of temporal information. In the case of backwards causation or time travel, one can think of ways of reversing the arrow of time, but that requires the idea of temporal direction from the onset. In this sense, the psychological work reviewed above shows how causal thinking develops in connection to temporal sequence. If the possibility of, say, time travel were proven, this would require people to significantly readjust their conceptual framework, particularly causal understanding. Similarly, if causality were proven to be more fundamental than time, people's usage of a conceptual connection going the other way around would explain their difficulties in understanding temporal order in terms of causal order. Thus, my claim that people understand the causal asymmetry through temporal sequence would still stand. I should also note that this solution goes along similar lines with my treatment of simultaneous causation. Nevertheless, while people have shown the ability to use models accommodating simultaneous causation, backwards causation or time travel may require a radical change of causal models. Likewise, the ability to use evidence for causal structures other than temporal information enables both ruling out joint effects, and thinking about causal connections that do not necessarily follow the arrow of time.

A further thing to note is that the philosophical investigation of these cases itself involves an understanding of causation which, I argue, matches the ordinary understanding insofar as temporal sequence is involved. The cases discussed above, which aim at showing that the order of causation does not always match the order of time still presuppose an understanding of causation in temporal

7 Another example under psychological research is mental time travel – while people can mentally switch between past and future scenarios, this capacity obviously is in no way dependent on the possibility of time travel.

terms. Taking a standard example of simultaneous causation – a steel ball causing a cushion to stay depressed (Kant 1781) – a complete understanding of the state of affairs includes considering a previous state when the steel ball is placed on the cushion, and the cushion is gradually depressed. It is possible to go as far as to inquire whether one could tell that the steel ball causes the cushion's depressed state if one has never seen instances akin to placing a steel ball over a cushion thus causing it to depress. Thus, while from a philosophical perspective there are possible counterexamples to challenge the connection between the temporal and causal direction, the way causality is understood even in such cases presupposes temporal sequence.

The framework proposed here can further explain the conceptual connections between causation and action and integrate them with the psychological studies discussed above. Particularly, I focus on the question whether the causal asymmetry follows the asymmetry of control – i.e., actions are ways of bringing about outcomes, but not the other way around. Mackie's (1956) investigations of the causal asymmetry (or, in his words, causal priority) argue that the relation goes the other way around – the causal asymmetry is already at use when considering the asymmetry between actions and their outcomes: 'it is true that our knowledge of the direction of causation in ordinary cases is thus based on what we find to be controllable, and on what we either find to be random or find that we can randomize; but this cannot without circularity be taken as providing a full account either of what we mean by causal priority or of how we know about it' (262-263). While I do not investigate what causal priority is here, my account can answer the latter question, regarding how we learn about it. The framework introduced in this section holds that causation is taken to be asymmetric in virtue of its connection to temporal sequence. Upon learning about new causal connections by acting, one already assumes causation follows a direction, as witnessed in temporal sequence. Thus, as in the example above, the ordinary understanding of causation is shown to provide the assumptions which drive causal thought, in this case, in relation to action.

To conclude, this investigation shows how the ordinary understanding of causal concepts shapes philosophical talk about causation. This approach brings several advantages. Firstly, it helps integrate philosophical and psychological research about causality, namely concerning how people think about causation and time. As already pointed out, this understanding need not be correct, and in this sense, my investigation can assist normative inquiries. If people tend to connect causality to temporal sequence, while this does not always hold for causal occurrences in the world, knowledge of this ordinary understanding would render one aware of the most common errors in causal reasoning. Secondly, it presents debates concerning causal concepts such as backwards causation in a different light, taking psychological information into consideration. Here, too, further

investigation is possible. If backwards causation contradicts the inference from temporal sequence to causality, what are the psychological mechanisms rendering such concept possible? A potential lead here would be imagination, which has been linked to causal reasoning (Harris et al. 1996, Walker and Gopnik 2013), but not concerning these particular cases. Thus, the proposed view suggests that how we think about causal concepts is influenced by how we learn about causality. In this sense, philosophical and psychological investigations can be jointly employed to make sense of various instances of causal thought and conceptual connections.

5. Conclusions

I have advanced a model of causal understanding where the causal asymmetry follows the direction of time while other asymmetries, such as that of action, come into place in subsequent reasoning, once causal order is understood through temporal succession. In psychological context, I have argued for a preliminary understanding of causality that can be subsumed under the knowledge-based causal induction, and more broadly under causal models – i.e., causal inference starts from hypothetical knowledge of causal structure. There is evidence for the employment of this model both in developmental research, and in adult causal reasoning. I have further provided a broader perspective on causal understanding, where the assumption that causes precede their effects can be traced within the ordinary understanding of causal concepts, as well as within philosophical debates on the causal asymmetry. Particularly, I have shown how concepts such as backwards causation and time travel are understood in the light of a preliminary concept of causation that aligns with temporal order. Along the same lines, I have explained how this preliminary understanding is also present when describing causality in terms of the relation between action and outcome.

This approach, thus, helps bring together people's ordinary understanding of causation with psychological studies of causal reasoning and philosophical work on causal concepts, while also touching upon metaphilosophical issues: as temporal order is an important source of hypotheses regarding causal structure, it shapes subsequent uses of causal concepts and means of inferring causally. This explains the intuitive connection between causality and time, and even if it does not always yield into correct judgments of causal structure, from a normative perspective, it can be used to identify cases where causal thought may be unreliable. The view on causal cognition sketched out here can be enhanced by work on other cues to causation such as counterfactuals, or action. Another avenue for further investigation opened here concerns the origin of causal concepts and their connection to the temporal asymmetry.

Acknowledgements

I would like to thank David Lagnado, Phyllis Illari, and Federica Russo for comments on the dissertation chapter from which this article draws. I am also grateful to Matteo Colombo and Jan Sprenger for feedback on a related project during a fellowship at the Tilburg Center for Logic, Ethics, and Philosophy of Science that has helped shape this paper. I would also like to thank one anonymous referee and the editor of this journal for suggestions on improving the main argument.

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