**AGENCIA EIDETICA Y CAUSALIDAD**

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A partir de los fundamentos de la propuesta de una agencia eidética (Fonseca, 2020) que consiste en un modelo en torno a la teoría de la acción, que asume una visión extensiva y andamiada de nuestro sistema epistémico y su normatividad, la ponencia pretende mostrar a la causalidad como una aplicación filosófica de modelos formales de razonamiento. Siguiendo los postulados de Hume (1748), Lewis (1973) Halpern y Pearl(2005) y principalmente de Spohn (2012), se planteará el argumento, según el cual, la causalidad es un modelo eidético de razonamiento y agencia.

## Causalidad

La filosofía ha tratado el problema desde el origen de la disciplina misma. No obstante, existen ciertos hitos fundantes en el desarrollo del problema. En la denominada filosofía antigua, Aristóteles y ulteriormente algunos filósofos de la Edad Media, afirmaban una realidad objetiva de la causalidad en conexión con la idea de sustancia y el ocasionalismo (Aristoteles, *Met*., I, 3, 983 a, 26 a, II, 2. and VII, 8, 1033 b).

El segundo hito es el escepticismo causal de David Hume (1748) inicia una visión clásica del problema de la causalidad desde una perspectiva crítica a la necesidad de la causalidad. Hume afirma al respecto:

When we look about us towards external objects, and consider the operation of causes, we are never able, in a single instance, to discover any power or necessary connection; any quality, which binds the effect to the cause, and renders the one an infallible consequence of the other. We only find, that that the one does actually, in fact, follow the other. (Hume, 1748, VII.63).

Hume argumenta que los conceptos son meras copias de nuestras experiencias. Así, el punto, siguiendo a Hume, es que no podemos tener una experiencia directa o impresión de aquello que sea la causalidad; los eventos simplemente parecen estar cojoined, mas no conectados. Cartwright comenta la propuesta de Hume de la siguiente forma:

Human beings, he believed, are deeply prone to forming habits. So, having observed a regular association between two kinds of events, we come to expect the second when we see the first. Looking inwards at ourselves, we notice this feeling of expectation; we get an impression of it. Our concept of causation, Hume claimed, is a copy of that impression of expectation. All that is happening in the external world that contributes to our coming to have this concept is a regular association of events. The concept itself derives from an impression of our internal state. (Cartwright, 2014, p.309)

La idea de una conexión necesaria, con respecto a la causalidad, es percibida no entre eventos , sino entre las ideas de los sujetos. (Beebee, 2006, p.85). La de finición de causalidad de Hume es doble como veremos a continuación: *“we may define a cause to be an object followed by another, and where all the objects, similar to the first, are followed by objects similar to the second. Or, in other words, where, if the first object had not been, the second never had existed”* (Hume, 1748, VII).La primera definición nos lleva a una perspectiva que comprende la causalidad como regularidad y una segunda, a saber, la alternativa probabilística y contrafáctica sobre la causalidad.

La perspectiva de la regularidad es, siguiendo a Pilos (2009), la versión opuesta a la tesis clásica de la relación productiva de la causalidad. Para esta propuesta, *c* causa *e* si y solo si:

1. C es espacio temporalmente contiguo a E.
2. E se sucede en el tiempo.
3. Todos los eventos del tipo C son regularmente seguidos por, contiguos, a eventos del tipo E.

Esta propuesta es entonces comprendida como un conjunto de: “(…) patterns among events even if there were no minds around (…) one might think of regularity as the mereological sum of its instances” (Pilos, 2009, p.133). La perspectiva de la causalidad como regularidad está basada en una crítica al escepticismo de Hume y afirma a la causalidad como un elemento de la realidad independiente de cualquier concurso de la mente. Esto se soporta, a su vez, en la supuesta existencia de la regularidad en la naturaleza.

A partir de la compresión de que las leyes de la naturaleza son en un sentido fuerte algo muy diferente de las regularidades, esta propuesta devela ciertas falencias fundamentales. Por ejemplo, la controversia sobre la sucesión del día y la noche sostenido por (Reid, 1788) y Brown (1822) explicita el problema. ¿Es el día una causa de la noche dada las premisas de la propuesta de la regularidad? Tal tipo de contraejemplos conllevan a una propuesta de condiciones y estructuras con respecto a la relación causal. JS Mill propone una lectura que define a las causas no solamente como regularidades, sino como regularidades bajo ciertas condiciones: *“The cause then, philosophically speaking, is the sum total of the conditions positive and negative taken together”* (Mill, 1911, p.217). Las condiciones necesarias y suficientes muestran como las regularidades que conforman las leyes de la naturaleza son parte de una estructura, valga decir, mental.

Siguiendo el aire de familia de la argumentación de Mill, Ramsey propone una explicación plausible: aún si pudiéramos conocerlo todo, nosotros seguiríamos buscando formas de sistematizar nuestro conocimiento como un sistema deductivo, y los axiomas generales en dicho sistema constituirían la justificación de las leyes de la naturaleza. La escogencia de tales axiomas está atada en un fuerte sentido a la arbitrariedad, pero lo que no parece ser tan arbitrario, si alguna simplicidad quiere ser guardada como fundamento del cuerpo de la generalización dada en tales leyes, implica tomar ciertos axiomas como goznes y otros como necesariamente deducidos (Ramsey, 1928, p.12).

Por lo tanto, es possible añadir una definición estándar de la causalidad como regularidad en tanto: *“c causes e if and only if c belongs to a minimal set of conditions that are sufficient for e given certain laws”* (Meinzes, 2017, p.1.1).

Sin embargo, muchos problemas permanecieron desde las propuestas derivadas del debate de Reid y Brown y sus mejoras (Mackie, 1980). La primera hace referencia a la imperfección de las regularidades. El ejemplo típico es la relación entre fumar y la aparición del cáncer de pulmón ya que algunos fumadores no lo desarrollan. LA segunda es la irrelevancia de ciertas regularidades. Esta es una suerte de falacia *non causa pro causa* por coincidencia; maldecir a alguien cada vez que fuma no es la causa de su cáncer de pulmón. Otro problema de la tesis de la regularidad es la asimetría o el tipo de falacia *non causa pro causa* de la causalidad reversa; el cáncer de pulmón no es la causa de que alguien fume. Finalmente se puede hablar de regularidades espurias. El ejemplo de Jeffrey (1969) es muy claro: el descenso de la presión barométrica y el descenso de la columna de mercurio es una regularidad espuria con respecto al efecto, es decir, la tormenta. Hitchcock (2018) retoma el ejemplo del cancer de pulmón para señalar estos problemas e introducir la noción de probabilidad en la causalidad como una forma de solucionar estos problemas: *“Thus, smoking is a cause of lung cancer, not because all smokers develop lung cancer, but because smokers are more likely to develop cancer than no smokers”* (Hitchcock, 2018, p.2.3).

La motivación general con relación a la probabilidad es recogida por el conjunto de propuestas denominadas teorías probabilísticas sobre la causalidad. Dichas teorías se fundan en la idea raíz que Cartwright afirma a continuación:

When a cause is present there should be more of the effect than if it were absent. That is the root idea of the probabilistic theory of causation. If C –type events occurring at some arbitrary time t cause E –type of events at a time t´ later, then we should expect: P(Et/Ct) > P(Et¨/¬Ct). (Cartwright, 2014, p.313)

The *relata* of probabilistic causation theories with respect to actual causation are often called *events*. General causal relata are often called *factors*. Events are random variables in a probability space. Hence, causation is thus related with the raising of the probability of an event *e* given an event *c*. This is the *root idea* common to several approaches to probabilistic causation like Reichenbach (1956), Suppes (1970) and Cartwrght (1979).

Reichenbach (1956) introduced several important notions to this reading. First of all, is the notion of *screen off*: If *P (E∣A∩C)) =P (E∣C)*, then *C*is said to *screen* *A* *off* from *E*. Therefore, *A* and *E* are independent. Hitchcock clarifies the matter as follows:

Reichenbach recognized that there were two kinds of causal structure in which C will typically screen A off from E. The first occurs when A causes C, which in turn causes E, and there is no other route or process by which A effects E(…) We might say that C is an intermediate cause between A and E. (…) The second type is a common cause of A and E. (Hitchcock, 2018, p.2.3)

The second type of screen off is represented by the barometer example upon. A drop in pressure causes the drop of mercury and the storm, but air pressure *screen off* the measure, because this does not affect the occurrence of the storm. In this sense, Reichenbach developed the notion of *common cause principle[[1]](#footnote-1)*. Ultimately this not actual causal relations of two separate events are determined by a common causal probabilistic relationship. Nevertheless, this notion is problematic with respect to the *root idea* of probabilistic accounts. First, in some cases, *c* and *e* can have a common cause and therefore, the *root idea* is necessary but not sufficient to explain causation. Second, this common causes can rise relations called *reverse inequalities* given certain contexts that make not necessary our *root idea*. This is cleared in the so called Simpson´s paradox (1951)[[2]](#footnote-2).

Cartwright (1979) wanted to solve these problems through the notion of *background contexts*. The core idea is that: *C* causes *E* iff *P (E/C∩B) > P (E/¬C∩B)* for every background context *B*. Hence, *Background context* is a sum of variables that in the frame of our *root idea*, like is patent in the previous formula, become fixed as a kind of constant. Given *B* a cause *C* *must* raise the probability of *E* in every background context. This position leads to a debate on the scope of the background context and the beginning of certain causal modeling and interventionist approaches.

Another branch derived from Hume´s twofold definition and probabilistic root idea is the approach named the *counterfactual theories* of causation. These are based on the semantics of counterfactuals made explicit by Stalnaker (1968) and Lewis (1973). We can define it generally following Paul´s reading:

That is C causes E because the counterfactual If not C, then not E is true. To the extent that this is successful, we have a counterfactual analysis of causation (…) Counterfactuals are subjunctive conditionals of the form, if it were the case that A, then it would be the case that B. (Paul, 2009, p.158)

Lewis theory is based in certain asymmetry or over determination of facts with respect to a counterfactual *a priori* conceptual analysis (Meinzes, 2017). From this point of view, causes are something that *makes a difference*. Counterfactual dependence between two distinct *possible* events leads to a causal dependence of two distinct *actual* events. Hence, events behave with transitivity, this is to say, causal dependence is successful if it belongs to a certain causal chain of actual events (Lewis, 1973, p.563). In that sense, there is either a temporal asymmetry of causal dependence; the *present* counterfactually depends on the *past*. (Lewis, 1973, p.567) Finally, Lewis lecture argues that there is no space for *backtracking counterfactuals* or certain preempted potential causes because the premises of transitivity and actual causal chains make clear that potential causes are related with the counterfactually concept of dependence but not with actually causes. That is why: *“Causal dependence is sufficient for causation but not necessary: it is possible to have causation without causal dependence”* (Menzies, 2017, p.1.2). Lewis actual causation is then based on the transitivity closure of counterfactual dependencies. The problem with this chain of events is that the effects not always depend counterfactually on their causes and not even directly. Counterfactual accounts, given this, suffer with several problems like preemption, redundancy, backtracking counterfactuals, simultaneity and trumping. However, the counterfactual approach has certain virtues that have been exploited by later theories of causation. Paul claims on these virtues:

A general theoretical motivation for a reductive analysis of causation is that such an analysis would be deeply related to many other central philosophical topics, and would serve as a tool for philosophers, scientists, and others to use. (Paul, 2009, p.166)

Halpern and Pearl (2005), in continuity with the probabilistic and counterfactual approaches, formulate a definition of causality in relation to the language of *structural equations*. This causal modeling approach sets new methods to grasp causal relationships and new answers to its inner problems.

Here we give a definition of actual causality cast in the language of structural equations. The basic idea is to extend the notion of counterfactual dependency to allow contingent dependency. In other words, while effects may not always counterfactually depend on their causes in the actual situation, they do depend on them under certain contingencies. (Halpern and Pearl, 2005, p.844)

This definition allows solving, for instance, problems as preemption and redundancy. The truth of the causal claims is relative to a certain model, and the model is relative to a certain context or background. They claim that in that sense:

It is possible to construct two closely related structural models such that C causes E in one and C does not cause E in the other. Among other things; the modeler must decide which variables (events) to reason about and which to leave in the background (…) models of the world is a better representation of those aspects of the world that one wishes to capture and reason about. (Halpern and Pearl, 2005, p.845)

A set of random variables and functions build an equation that represents several mechanisms that modeled the way in that the variables influence others or cause others. Variables behave in this way:

In practice, it seems useful to split the random variables into two sets, the exogenous variables, whose values are determined by factors outside the model, and the endogenous variables, whose values are ultimately determined by the exogenous variables. It is these endogenous variables whose values are described by the structural equations. (Halpern and Pearl, 2005, p.847).

The system of equations requires random variables that support the direct and deterministic relationships of the model to shore up the adequacy of the variables influence the model. This makes it possible to avoid problems of preemption, simultaneity, and redundancy. However, the proposal suffers certain weaknesses.

It may seem strange that we are trying to understand causality using causal models, which clearly already encode causal relationships. Our aim is not to reduce causation to non-causal concepts but to interpret questions about causes of specific events in fully specified scenarios in terms of generic causal knowledge such as what we obtain from the equations of physics. The causal models encode background knowledge about the tendency of certain event types to cause other event types. (Halpern and Pearl, 2005, p.849)

The proposal, beyond the warning of the authors, falls into a certain circularity, as Cartwright declares in (1979) because the variables that they set as background, are not understood as causes themselves; in the end, exogenous variables seem to determine the whole mechanism of causality. Halpern and Pearl's theory seems to be an interventionist account on causality, in a certain sense, a *means- end* reading of causation. Exogenous variables are fixed as the obtaining circumstances of the *particular* causal process modeled.

Spohn´s *workable* alternative (2006), which is our main task, seeks to solve all these problems thanks to the benefits of *ranking theory* and its account of induction and dynamics of belief. In the same path of counterfactual, probability and causal modeling proposals, Spohn starts his theory perhaps at the beginning of the problem, that is to say, Hume´s definition:

The paper builds on the basically Humean idea that A is a cause of B iff A and B both occur, A precedes B, and A raises the metaphysical or epistemic status of B given the obtaining circumstances. (Spohn, 2006, p.93)

The improvement of this basic idea, which Spohn makes clear in (2012) is due to the relationship established between inductive inference, to which the second chapter of this work was devoted, and the causal inference. The first step to establish this relationship is then to fix the conceptual framework of his theory of causation. First of all, Spohn framework deals with particular causation. General causal processes are a later business to deal with. Spohn´s account as we saw in § 2.3 uses the language of *variables,* not *events*. Variables are specific objects at a certain time and with certain properties. To be the case for these properties of the variable is the *realization* of such variable. Hence, all these small worlds in § 2.3 are in one dimension ontological states of affairs and in other dimension epistemic propositions (Spohn, 2006, p.96). It is important to say that this set of variables is finite. Besides this, Spohn assumes determinate temporal relations with respect to causal processes:

For instance, a specific game of chess certainly is a causal process, and the natural variables to consider are all the possible moves of the game. The exact points of time at which the move occur may be taken to be irrelevant; what matters is only the temporal order of the moves. (Spohn, 2012, p.342).

Therefore, Spohn represents the temporal relations as follows: *“I will usually write X<Y and X≤Y in order to express that X precedes or is realized before (or at the same time as) Y”* (Spohn, 2012, p.341). It entails a discrete temporal order for this model of causation. *X-propositions* or atomic propositions represent the variables and are the *relata* of causal relations. Causal relations *are* relations between atomic facts. With respect to temporal relations, *A* can be a cause of *B* only if *A* is not later than *B*. Spohn´s proposal is thus grounded in the asymmetry of temporal precedence:

General relativity theory has inspired fantasies about backwards causation, and so do certain obscure quantum effects. All this is far beyond my ken. Let me simply state that none of the subsequent theorizing would work without this assumption. (Spohn, 2012, p.351)

At this point, he returns to his earlier definition in (2006); given this framework and the advances of ranking theory he defines causation as:

A is a cause of B iff A and B obtain, A precedes B, and A is a reason for B given the obtaining circumstances. (Spohn, 2012, p.354)

This is an epistemic reading based on the conception of reasons as the relation between ranking functions. Spohn claims then: “Thus like Hume, I take causation to be an idea of reflexion; I am bound to claim that causation is in the eye of the beholder” (Spohn, 2012, p.340). Causality is a sort of epistemic relation. It is based not in physical probabilities or mechanisms but in doxastic agent´s reasons. Therefore, causes are conditional reasons (See: § 3.2). In that sense, as ranking theory distinguishes kinds of reasons, hence we obtain kinds of causes:

Therefore, we will be able to equally naturally distinguish supererogatory, sufficient, necessary, and insufficient causes. Necessary and sufficient causes are the focus of the traditional accounts. (Spohn, 2012, p.354)

Obtaining circumstances following Spohn are defined as all the other causes of *B* that are not caused by *A*. This definition falls, apparently, in the circularity objection of Cartwright (1979). Spohn answers with this proposal:

However, the circularity dissolves, if only A´s being a direct cause of B is considered. In this case there are no intermediate causes, i.e. no causes of B caused by A; the relevant circumstances may hence include all other causes of B. (Spohn, 2006, p.104)

For instance, a *causal chain* A→B→ C given the negative ranking *k*(A)=*k*(¬A)=0 shows that *A* screens off *B* from *C*.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| k(.│A) | C | ¬C |  | k(.│¬A) | C | ¬C |
| B | 0 | 1 |  | B | 1 | 2 |
| ¬B | 2 | 1 |  | ¬B | 1 | 0 |

And with respect to a *conjunctive fork* A→B and A →C something similar happens.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| k(.│A) | C | ¬C |  | k(.│¬A) | C | ¬C |
| B | 0 | 1 |  | B | 2 | 1 |
| ¬B | 1 | 2 |  | ¬B | 1 | 0 |

All this because the ranks *count* the violations of causal relations and therefore more violations lead to more disbelieve (Spohn, 2006, p.106). Hence, the epistemic direct causation account seems to solve circularity problems. In this sense, Spohn (2012) improvement gave us a powerful tool to clarify and interpret causation with respect to ranking functions:

*“The following paradigmatic ranking tables in terms of two sided ranking function τ derived from the basic negative ranking function ξ are instructive:*

|  |  |  |
| --- | --- | --- |
| τ(C│.) | B | ¬B |
| A | 1 | -1 |
| ¬A | -1 | -1 |

1. *joint necessary and sufficient causes*

|  |  |  |
| --- | --- | --- |
| τ(C│.) | B | ¬B |
| A | 1 | 0 |
| ¬A | 0 | -1 |

1. *joint sufficient, but not necessary causes*

|  |  |  |
| --- | --- | --- |
| τ(C│.) | B | ¬B |
| A | 1 | 1 |
| ¬A | 1 | -1 |

1. *redundant causes” (Spohn, 2012, p.364).*

The tables a) and b) are in a certain sense common in theories of causation, but table c) is a novelty to solve several inherited problems of the predecessor theories. The first one is *overdetermination*. In this case, two or more independent causal processes produce the effect.

|  |  |  |
| --- | --- | --- |
| τ(C│.) | B | ¬B |
| A | 2 | 1 |
| ¬A | 1 | -1 |

*“Overdetermining causes” (Spohn, 2012, p.366).*

This kind of causes is related to the notion of supererogatory reasons. “For instance, to avoid the notorious cruel firing squad, the prince sings a love song (A) and accompanies it by playing the mandolin( B) in order to wake up the beloved princes (C)” (Spohn, 2012, p.365). Ranking theory explains it better than fine graining events, structural contingencies and regularity proposals.

The second case is the classic problem since Lewis (1973) of preemption by cutting. As table (c) represents better “ The classic example introduced by Hart, (Honoré,1959, p.219) is the story of the desert traveler, which starts with the first assassin pouring poison into the traveler´s water keg, continues with the second assassin drilling a hole in the keg, and sadly ends with the traveler´s death in the desert ” (Spohn, 2012, p.365). Counterfactual approaches are very worried about potential preemption, and backwards causation. However, ranking theory approach deals with these problems easily. In this sense, preemption by trumping is represented with this table:

|  |  |  |
| --- | --- | --- |
| τ(A│.) | S1 | ¬S1 |
| M1 | 2 | 2 |
| ¬M1 | 1 | -1 |

“Trumping, binary case” (Spohn, 2012, p.368).

The classic example with respect to this causal problem is the following as described by Lewis (2000, p.81):

The Sergeant and the Major are shouting orders at the soldiers. The soldiers know that in the case of conflict, they must obey the superior officer. But as it happens, there is no conflict. Sergeant and Mayor simultaneously shout Advance!; the soldiers hear them both; the soldiers advance. Their advancing is redundantly caused: If the Sergeant hat shouted Advance! And the Mayor had been silent, or if the Mayor had shouted Advance! And the Sergeant had been silent; the soldiers would still have advanced. But the redundancy is asymmetrical: Since the soldiers obey the superior officer, they advance because the Mayor orders them to, not because the Sergeant does. The Mayor preempts the Sergeant in causing them to advance. The Mayor trumps the Sergeant.

According to the table representation, we do not need to appeal to fine graining causal chains or specified models for each asymmetrical case but just to appeal to reasons. Sergeant’s shout is a necessary and sufficient cause and Mayor´s shouting is a supererogatory cause. Spohn´s causation theory is thus a good modeling tool for several theoretical and practical purposes. In this sense, he claims that:

These examples aptly show how, already in the case of direct causation, the ranking-theoretic account provides us with greater expressive means than all rivals. These means allow us to take our intuitions at face value without further ado. Of course, the modeling of examples is hardly ever unique; as Halpern, Pearl (2005a) emphasize again and again, there often are several plausible alternatives, and several manners of causal talk are thus representable. Still. I submit that ranking theory enriches our modeling options in plausible and unprecedented ways. (Spohn, 2012, p.369)

Now, given all this, how is possible to extend this local direct causation model to a general causation account?

I do not speak about repetitions generalizations, or causal laws, though I do suggest that this is a simple step, once we have successfully dealt with the single case. Or to be explicit: If ξ describes the causal relations in the given single case, then the law λξ is the causal law that generalizes to all like cases. Of course, causal laws may only be ceteris paribus laws. We may embed all of our considerations about the single case into a background of normal conditions. The corresponding generalization will then produce only a ceteris paribus causal law. (Spohn, 2012, p.357)

The law *λξ* is then, as explained in the previous section, a *ceteris paribus law*. In Spohn (2006, p.115) he claims that *λ* is the conjunction of all causal conditionals with respect to *ξ.* This leads to a normal conditions proposition or ceteris paribus clause with respect to a certain frame or causal like set. A causal law is a kind of subjective law, a mind-relative notion of causation.

The last problem that Spohn´s causation theory faces is relative to the costs of a subjective or epistemic perspective of causation. This is the problem of objectification. Spohn (2012, Ch15) claims that we can choose between three different paths. The first is just to ignore the issue and use the tools of the theory in a *means –end* perspective. Following a second perspective, one may be *ecumenical* and say that the theory can have several interpretations. Finally, the last way is to get involved in the problem of a mind independent notion of causation principally with respect to the ontological commitments of the natural sciences. Spohn follows the last path and starts a *projectivistic* approach.

To be explicit, an objective (possible) law is true or false generalization backed up by an objectifiable persistent ranking function, and an objective causal pattern (or law, if generalized) is a true or false pattern of succession backed up by a ranking function that is objectifiable w.r.t. its (subjective) causal relations. Or as I titled my (1993a): causal laws are objectifications of inductive schemes. (Spohn, 2012, p.469)

At this point is important to claim that for the purposes of this work perhaps we don’t have certain costs to pay. This, just because, the ontological commitments with respect to social reality as we set in § I.2 are purely mind-relative. Social reality is a product of -at least at this moment- human minds and therefore is epistemic and mind-relative. This model of causation then is workable for our purposes and, just for the moment, to take the first or the second path is quite enough.

1. Following the explanation of Hitchcock (2018) of CCP: given P(*A*&*B*)>P(*A*)×P(*B*) and neither *A* nor *B* is a cause of the other, there will be a common cause, *C*, of *A* and *B*, satisfying the following conditions:

i. 0<P(C)<1

ii. P(A&B∣C)=P(A∣C)×P(B∣C)

iii. P(A&B∣∼C)=P(A∣∼C)×P(B∣∼C)

iv. P(A∣C)>P(A∣∼C)

v. P(B∣C)>P(B∣∼C). [↑](#footnote-ref-1)
2. This is an example from (Melinas and Bigelow 2016) on Simpson´s paradox: a/b <A/B , c/d <C/D, (a+c)/(b+d) >(A+C)/(B+D) or 1/5 <2/8 , 6/8 <4/5, 7/13 > 6/13. [↑](#footnote-ref-2)