How to Make a Proceedings Paper Submission

Anonymous CogSci submission

Abstract

Keywords:

Introduction

Identifying the causes of an event involves not only logical rules but also different senses of "causation" that people might have. Let's imagine that, to mitigate false alarms rate and improve the detection of fires, Lilly decides to install at home a dual alarm system that goes off if and only if two chains of ionization and photoelectric detectors are triggered (Fig.1a). Lilly wants to test her new system by exposing the detectors to some smoke. At some point a ionization detector starts beeping first while measuring a change in the electrical conductivity of air. It activates the next detector in the sequence which then activates the last one (Fig.1b). At this stage Lilly notices that the alarm remains silent. After a while a photoelectric detector starts beeping as well while measuring a change in the transparency of air. It activates the next detector in the sequence which then activates the last one and right after the alarm goes off (Fig.1c).

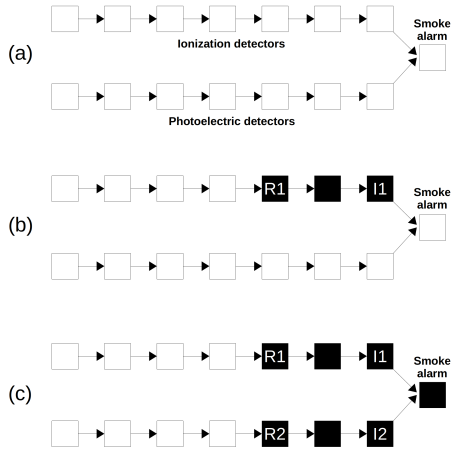


Figure 1: This is a figure.

What would Lilly think caused the alarm to go off? Several answers can be considered. Based on logical dependencies, people's causal judgements can state that both the furthest activated ionization detector (first root change "R1") and the furthest activated photoelectric detector (second root change "R2") are equally the causes of the alarm activation. However a more intuitive answer would be that the provided temporal information influences people's choice toward one cause more than the other one. An important selection criterium could be how recent a candidate cause is compared to another one and would lead for instance to the following preferences: R2 $\succ$ R1, and I2 $\succ$ I1 ("I2" and "I1" being respectively the second and first immediate changes). Nonetheless we can imagine other cases where people potentially rely in part on another type of temporal criterium: let's imagine that the activation of the ionization detectors starts before and finishes after the activation of the photoelectric detectors (such that R1 and I2 belong to the same sequence and *idem* for R2 and I1). In that case the activation of the furthest photoelectric detector is still the most recent but it doesn't initiate a sequence that leads to the activation of the alarm anymore, whereas this is the opposite for the furthest ionization detector. In such situations we want to know what people would consider as the main cause of the system.

The alarm case can be seen as an example of "singular causation"[1] where we want to understand, in a singular context, what caused a particular event to occurr at the time it did. More generally it instantiates a class of causal systems where an event is a common effect of distinct sequences of necessary causes. [[Those kind of causal systems are very common in real life and can involve finding who or what is at fault in dramatic accidents, property damage, crimes, etc.. Understanding why people, in a specific situation, decide for one candidate cause rather than another one can lead to better support important decisions (e.g. legal ones) and help us better predict causal judgements that are made in specific contexts.]] Causal judgements have been widely studied in the litterature, however we think that the temporal order in which each variable changes its value is an important feature of causal systems that have been hardly studied nor tested experimentally as we intended to do. Indeed current research on actual causation mainly relies on two different interpretations of causality that don't ground causal judgements on temporal information: the counterfactual (CF) and the physical process (PP) accounts.

According to the CF account, the general idea is that an

[1] Also called "token" or "actual causation" by opposition with "general causation" – following a distinction that has been frequently made in the litterature.

event A is said to be a cause of a distinct event B if the occurrence of A makes a difference in the occurrence of B. More precisely A is a cause of B if and only if A and B are true, and A hadn't occurred B wouldn't have occurred. This interpretation calls upon counterfactual scenario or possible worlds where the presumed cause of the effect is removed from the system while all other relevant factors are kept as unchanged as possible compared to the actual world. According to us the main problem of this interpretation is that its best models explicitely rejects the idea of grounding causation on temporal information. In that framework events are represented as mere propostions and causation is thought as a relation between static states.

According to the PP account, an event A causes B when there is a physical connection between them. In one of its latest and probably most convincing formulation, this theory distinguishes two things : causal process and causal interaction (i.e. causation). A causal process is a physical process involving an object which conserves a certain quantity, like mass-energy, accross space and time. A causal interaction or causation is an exchange of that conserved quantity. However the theory goes sometimes against some of our best causal intuitions and to makes implicitely use of the CF analysis to explain our judgements: if I hold the head of my ennemy under water and make him die, I'm not genuinely the cause of his death; rather I'm actually preventing the possibility of a genuine causation which is breathing oxygen in order to live. Moreover, the PP account is meant to give an epistemological definition of the concept of causation and not an explanation of how people actually rely on temporal informations to make causal judgements.

Theoretical proposition

As a result of the preceeding analysis it seems that none of the current main theories of actual causation has focused on the role of temporal information for inferring causal relationship between events qua changes of states over time. In contrast we hypothesised that people's causal judgements are influenced by not only the values of all relevant variables at the time the effect occurs, but also the temporal order in which these variables took their values. This approach has some precedent in the literature but has not been developed carefully and has never been tested experimentally as we intend to do. We add further that people mainly identify causation with a *continuous* sequence of changes of states over time. The underlying intuition is that people trace back the history of changes from the immediate one that directly brought about the occurrence of the effect, up to the root change in the system that initiated the series of changes along the path. As we think that in common life it is really rare to see simultaneously two or more events occurring at the very same time and producing some common effect, we also want to postulate a *no coincidence principle*. Relying on this principle we can split the system's time frame in units of time that are small enough to have no more than one event[2] per unit. Lets represent by $\mu^{\emptyset}_{z_{i\to j}}(t)$ a change of state at time t, from variable $Z = z_i$ to $Z = z_j$, $\forall i, j \in \mathbb{R}_+$. Here Z is the variable we want to reason about and has no children (represented by the empty set $\{\emptyset\}$). Formalizing our above mentioned idea we first have to find $\mathcal{U}^Z_{\boldsymbol{y}_{i\to j}}(t-1)$, that is the set of the immediate changes in the parents $\boldsymbol{Y}$ of the variable Z at time $t-1$ that led to the observed change in Z at time t. So we want to find $\mathcal{U}$ such that $\mathcal{U}^Z_{\boldsymbol{y}_{i\to j}}(t-1) \to \mu^{\emptyset}_{z_{i\to j}}(t)$. According to our *no coincidence principle* $\mathcal{U}$ is either empty or a singleton – including only one parent whose value changed. Lets say that at $t-1$ we find a change in a parent variable Y, so $\mathcal{U}^Z_{\boldsymbol{y}_{i\to j}}(t-1) = \{\mu^Z_{y_{i\to j}}(t-1)\}$. Then we want to find the set of changes such that $\mathcal{U}^Y_{\boldsymbol{x}_{i\to j}}(t-2) \to \mu^Z_{y_{i\to j}}(t-1)$, that is the set of immediate previous changes in the parents $\boldsymbol{X}$ of the variable Y at time $t-2$ that led to the observed change in Y at time $t-1$. Following the same logic we suggest that if $\mathcal{U}^X_{\boldsymbol{w}_{i\to j}}(t-3) \to \mu^Y_{x_{i\to j}}(t-2)$ is such that $\mathcal{U}^X_{\boldsymbol{w}_{i\to j}}(t-3) = \emptyset$, then it means that $\mu^Y_{x_{i\to j}}(t-2)$ represents the chronologically first change along the path, occurring in X, and we suggest that this change is identified as being the main cause of Z.

Experiments

To test our hypothesis that the main cause of an effect is the root change that initiates a continuous sequences of changes until the occurrence of the effect, participants were presented animations showing activation spreading over networks of nodes up to the final node. We run three different experiments which shared the same plot that we wanted as intuitive as possible: participants were told that they were working in a nuclear control room and that their job was to monitor networks of particule detectors. The instructions said that when a detector, depicted by a square or circle (see below), absorbs a radioactive particule it becomes active and turns black, transmitting the activation across the links of the network so that an active detector activates the next one in the chain and so forth. All the networks include a special component, called 'Gauge of Critical Moment', that becomes active only if all of its input from the detectors it is connected to are active. The Gauge of Critical Moment is always represented by a square with "GCM" (Experiment 1) or "G" (Experiment 2) above. At the end of an activation sequence, it is asked to click on the detector(s) they considered as the main cause(s) of the activation of the Gauge of Critical Moment. Examples of network activations were shown in the instructions and participants had to answer to answer a survey at the end to see if they correctly understood the instructions. If they made a mistake they had to read again all the instructions and answer again the survey.

In both experiments we included only two types of input-output logic, namely single input (chains) and AND-Gate (branches where the effect needs the activation of two inputs to occur). When people were presented chains, we first

[2] Again we insist on the definition of *event* as *change of state*.

wanted to see if they identified the main cause of the effect with a change of state that occurred in the chain the furthest away from effect (*root change*) or the closest to it (*immediate change*). When they were presented AND-Gates, we wanted to see if they identified the main cause of the effect with the root change that occurred chronologically first (*1st root change*, labeled "R1" henceforth), the root change that occurred chronologically last (*2nd root change*, "R2" henceforth), the immediate change that occurred chronologically first (*1st immediate change*, "I1") or the immediate change that occurred chronologically last (*2nd immediate change*, "I1").

Experiment 1

The objective of this experiment was to see whether people's causal judgement were influenced by: the length of the sequences of changes (for both chains and AND-Gates), and the delay between the 1st immediate change and the 2nd root change, that is between the end of the first sequence of changes and the beginning of the second sequence of changes (for AND-Gates only).

Participants. The experiment was hosted by Google Cloud App Engine and 30 participants were recruited via Amazon Mahchanical Turk. There were 10 females (average age: 37.3) and 20 males (average age: 37.6). 28 participants were english speakers, 1 were italian speaker and 1 marathi speaker.

Method. Each participant was presented 15 different networks of square detectors. Square detectors maintain their activation through time. Participants were first presented the network in its initial and static state and were asked to click the "Run" button to observe an activation sequence over the network. They waited 5000ms to see a first change of state occurring in a detector and the activation delay between any two successive detectors was set on 100ms (see Fig.1).

Three stimuli were chains that differed in length of activation sequence, that is including 2, 4 or 7 activated squares (with the GCM). These lengths were labeled "Short", "Medium" and "Long". The AND-Gates were similarily categorised "Short", "Medium" (like in Fig.1) and "Long" with both branches being the same length. In each length category participants were shown three similar AND-Gates that differed uniquely in the delays between the 1st immediate change and the 2nd root change. The delays were 2000ms, 4000ms and 6000ms.

All the stimuli were presented in a random order. Two groups, "Left" and "Right", were designed and partcipants were randomly assigned to either group at the begining of the experiment. In the "Left" group all the networks were shifted towards left (the GCM being on the left) and in the "Right" group all the networks were shifted towards right. For each AND-Gate participants saw randomly either the top branch or the bottom branch activating first.

After the activation of the GCM (the end of the animation) participants had to wait 1000ms before the squares became clickable and the following intruction appeared: "In this sequence what caused the activation of the GCM? Respond by clicking on a detector". They had the option to run again the animation (no more than 9 times) or to go to the next network assuming they clicked on one detector – they couldn't select more than one detector. When selected the edges of a detector turned red.

Results. Paragraph...

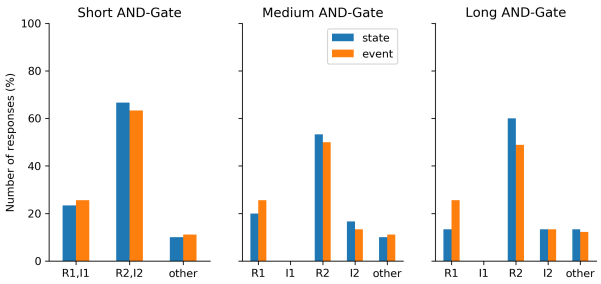


Figure 2: This is a figure.

Discussion. Paragraph...

Experiment 2

The objective of the experiment was this time to see if people's causal judgements are

Participants. The experiment was hosted by Google App Engine and 89 participants were recruited via Amazon Mechanical Turk. There were 29 females (average age: 39.7), 59 males (average age: 37.6) and 1 declared "other". All the participants were english speakers.

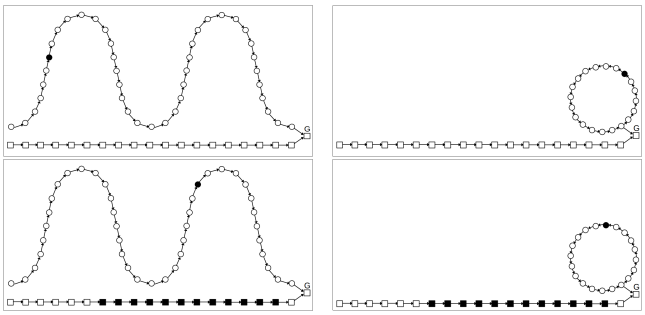
Method. Like in Experiment 1 each participant was presented 15 different networks. However this time we introduced round detectors that, contrarily to square detectors, don't maintain their activation through time. By adding this feature we were able to include networks that have a loop of detectors (see Fig.3b). 1 stimulus was a chain of square detectors and 1 stimulus was a chain of round detectors were included (for the latter one, only "G" remained a square). The other 13 stimuli were AND-Gates and were sorted into three main categories: 4 stimuli were Rolled networks, i.e. with a loop, as depicted in Fig.3b, 3 were Unrolled networks with square and round detectors as in Fig.3a, labeled "Unrolled circles" and 6 stimuli were Unrolled with square detectors in place of the round one (not represented here), labeled "Unrolled squares". For each category of AND-Gates all the stimuli were sorted according to two crossed dimensions: "Event" *vs* "State"and "R1 cont" *vs* "R2 cont". In condition "Event" none of the detectors is initially active or – if the branch is a loop – is continuously (re-)activated. In condition "State" one of the two branches contains initially detectors that are active or is continuously (re-)activated. In condition "R1 cont" (represented in Fig.3a) the activation is such that there is a continuous sequence of changes going from R1 to I2 that leads to the activation of "G". In condition "R2 cont" (not represented here) this is R2 that is continously connected to I2 that leads to the activation of "G". The design of the experiment

for the AND-Gates is given in Tab.1. For the AND-Gates (Rolled and Unrolled) the delay between I1 and I2 in condition "Event" was maintained at 11 nodes (i.e.1100 ms) for almost all the networks. There was only one Unrolled squares network for which the delay was set at 8 nodes (800ms).

		Unrolled		Rolled
		Squares	Circles	
Event	R1 cont	2	1	1
	R2 cont	2	1	1
State	R1 cont	N/A	N/A	1
	R2 cont	2	1	1

Table 1

As in Experiment 1 participants were first presented the network in its initial state and were asked to click the "Run" button to observe an activation sequence over the network. Participants waited 5000ms to see a first change of state occurring in a detector, except for the Rolled network case with activation already going around the loop (state condition) – in this case they had to wait between 3800ms and 5700ms before activation starts in the other branch. Activation delay between any two successive squares was set on 100ms as well.



(a) Unrolled circles. (b) Rolled.

Figure 3: Networks.

Results. Paragraph...

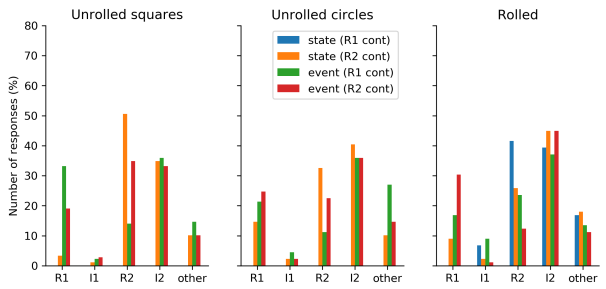


Figure 4: This is a figure.

Discussion. Paragraph...

General discussion