**The Sleeping Beauty Problem: What about Monday?**

In this paper I will defend the thirder solution to the sleeping beauty problem. More specifically, I argue that an examination of the credence Beauty ought to have, upon first awakening, that it is Monday can show why both the halfer and double-halfer solutions fail. Additionally, this approach indicates the nature of the inadmissible information that allows Beauty to assign credences that don’t match her belief about the objective chance of heads.

In section 1 I describe the sleeping beauty problem and very briefly state the halfer, double-halfer, and thirder solutions. In section 2 I explain David Lewis’s Principal Principle and characterize the problem in sleeping beauty as one of determining if and when, at any time during the experiment, Beauty has any inadmissible evidence. Then, in section 3 I show how considering Beauty’s credence that it is Monday leads to problems for the halfer and double-halfer but not for the thirder. Simply assuming that Beauty’s credences ought to obey the probability calculus leads the double-halfer to the result that Beauty’s credence, upon first awakening, that it is Monday ought to be 1. The same assumption, in conjunction with the assumption that Beauty’s credence, upon first awakening, that it is Monday shouldn’t be 3/4 unless she has evidence that favors Monday over Tuesday, leads the halfer into a contradiction; the halfer is forced to say that Beauty both has and lacks, upon first awakening, evidence relevant to the outcome of the coin toss. I end section 3 by showing that the credences Beauty must assign to Monday and Tuesday on the view of the thirder nicely parallel those she must assign to heads and tails. In section 4 I further defend the thirder position by providing two arguments similar in spirit to those of Adam Elga (2000) in that they begin by arguing that Beauty’s credence in heads, upon learning that it is Monday, ought to be 1/2. Finally, in section 5, I argue that Beauty’s knowledge, upon first awakening, that she is *now* undergoing an experimental waking is inadmissible. The reason it is inadmissible has to do with the fact that Beauty’s credence that the coin lands heads is probabilistically dependent on her credence that it is Monday. Beauty’s ignorance, upon first awakening, as to whether it is Monday or Tuesday plays a role in determining her credence that it is Monday, and so plays an indirect role in determining her credence in heads.

1. *The Sleeping Beauty Problem*

In the sleeping beauty problem a group of researchers conduct the following experiment. On Sunday evening the researchers will describe the experiment to Beauty before putting her to sleep. They will awaken Beauty for a short time on Monday. During this waking she will not initially know what day it is, but the researchers will eventually tell her that it is Monday. She will then be put back to sleep with a drug that will erase her memory of the Monday waking. The researchers may or may not wake her for a short time on Tuesday depending on the toss of a fair coin. If the coin lands heads they will wake her only on Monday, if it lands tails then they will wake her on Tuesday as well. Upon either of these awakenings Beauty will be in one of three scenarios: () it is Monday and the coin landed heads, () it is Monday and the coin landed tails, () it is Tuesday and the coin landed tails. These scenarios will be indistinguishable to Beauty: the result of the coin toss will not affect her total evidence upon awakening on Monday, and if the coin lands tails the memory erasure ensures that she will have the same total evidence at the Tuesday awakening as she had at the Monday awakening. Finally, the awakenings during the experiment are distinguishable from any other awakenings. Since Beauty knows the details of the experiment she will know, upon any experimental awakening, this she is currently in one of the scenarios described above.

On the assumption that Beauty always assigns credences as she ought to, the question we are interested in is, ‘upon first awakening, what is Beauty’s credence that the coin landed heads?’ I will follow Lewis (2001) in using different notation for Beauty’s credence function at different times. Let represent Beauty’s credence function *just before* she’s put to sleep on Sunday. Let represent her credence function *upon first awakening* on Monday. Let represent her credence function upon learning that it is Monday.

The problem is an interesting one in so far as there are compelling reasons in favor two different answers. Halfers argue that Beauty’s credence in heads ought to be 1/2, thirders argue that it should be 1/3. Halfers are further divided into regular halfers (hence forth, simply ‘halfers’), who think that Beauty’s credence in heads should increase when she learns that it’s Monday, and double-halfers who think that Beauty’s credence in heads should remain 1/2 at all times during the experiment. David Lewis (2001) appears to be the only explicit defender of the halfer position whereas Bradley and Leitgeb (2006), White (2006), Pust (2008, 2013), and Bradley (2011) raise challenges for thirders. Defenses of the double-halfer position can be found in Meacham (2008), Cozic (2011), and Hawley (2013). Various defenses of the thirder position can be found in Elga (2000), Vaidman (2001), Vaidman and Saunders (2001), Monton (2002), Arntzenius (2002), Dorr (2002), Weintraub (2004), Hitchcock (2004), Horgan (2004, 2007, 2008), Dieks (2007), Titelbaum (2008), Karlander and Spectre (2010), Groisman et al. (2013), Horgan and Mahtani (2013), Wilson (2014), and other works. Clearly the thirder position is the most dominant; still, my defense of the thirder position looks at a dimension of the problem that is normally ignored and shows how it leads to fatal objections to both halfers and double-halfers.

2. *The Principal Principle and Sleeping Beauty*

David Lewis’s Principal Principle (PP) connects rational credences to objective chances, where objective chances are objective single-case probabilities. Lewis initially describes PP as follows:

Let be any reasonable initial credence function. Let be any time.

Let be any real number in the unit interval. Let be the proposition

that the chance, at time of ’s holding equals . Let be any

proposition compatible with that is admissible at time . Then

. (Lewis 1980, 266)

PP says that if I believe that the chance of (at time ) is and if I have no inadmissible information, then I ought to set my credence equal to . So, if I believe that the chance that a coin about to be flipped will land heads is 1/2, and I have no inadmissible information, then my credence that the coin will land heads should be 1/2.

Lewis defines ‘admissibility’ as follows: “Admissible propositions are the sort of information whose impact on credence about outcomes comes entirely by way of credence about the chances of those outcomes” (Lewis 1980, p. 272). Consequently, inadmissible information is information that ought to affect my credence in but does not affect my credence in the chance of . This much seems uncontentious although it is a contentious issue exactly what kinds of propositions are, or are not, admissible. Fortunately, this characterization of admissibility is sufficient for my purposes.

PP provides a useful way to characterize the sleeping beauty problem as it indicates what defenders of the various positions need to accomplish. Either Beauty should follow PP in the absence of inadmissible information or she shouldn’t. On the assumption that she should, the problem becomes that of determining whether Beauty has inadmissible evidence at any point during the experiment. On the assumption that Beauty shouldn’t follow PP even when she has no inadmissible information, the problem becomes that of explaining why she shouldn’t. If Beauty shouldn’t use PP (either because she has inadmissible evidence or for some other reason), then there is the further issue of determining what her credence should actually be.

First consider the case where we accept PP. The halfer takes Beauty to have no inadmissible evidence on Sunday, no inadmissible evidence when she first awakens on Monday, and some inadmissible evidence upon learning that it is Monday. The thirder takes Beauty to have no inadmissible evidence on Sunday and some inadmissible evidence when she first awakens on Monday. If the thirder thinks that Beauty’s loss of information about what day it is renders her total evidence upon first awakening on Monday inadmissible, then they *might* think that Beauty’s total evidence is admissible when she regains that information upon being told that it is Monday. Other thirders, however, will take Beauty to have inadmissible evidence upon learning that it is Monday (the same inadmissible evidence she had before learning that it’s Monday). Finally, double-halfers take Beauty’s total evidence to be admissible at all times during the experiment.

The double-halfer must defend the claim that Beauty’s total evidence is admissible at all times during the experiment. The halfer must defend the claim that Beauty’s total evidence upon first awakening is admissible but that this evidence becomes inadmissible when the knowledge that it is Monday is added to it. The thirder must defend the claim that Beauty’s total evidence upon first awakening on Monday is inadmissible. Since the credence Beauty should have upon learning that it is Monday is to be determined by Bayesian conditionalization rather than by PP (even though they ought to match for the thirder that thinks that Beauty’s total evidence upon learning that it is Monday is admissible), completing the thirder defense requires only filling out enough information to do the calculation.

Now consider the case where we reject PP. Since PP appears to be a platitude about chance, one ought to have a strong argument if one wishes to reject it. If the sleeping beauty problem can give us reason to reject PP it would have to be by showing that any reasonable solution to the problem is such that conditionalizing on some admissible evidence (ex. that it’s Monday) changes Beauty’s credence in (ex. that the coin landed heads) without changing her credence in (ex. that the objective chance of heads is 1/2). But since changes Beauty’s credence in without changing her credence in , is inadmissible by definition. At best, the sleeping beauty problem can call PP into question by providing us with such an that is nevertheless *intuitively* admissible. However, that seems an insufficient reason to really question PP. So I think that we should accept that Beauty ought to adhere to PP in the absence of inadmissible information (and in the absence of reasons independent of the sleeping beauty problem for questioning PP).

So PP provides a useful way to determine what a defense of a solution to the sleeping beauty problem ought to involve. Beauty ought to accept PP and so the disagreement between halfers, thirders, and double-halfers can be characterized as a disagreement over the admissibility or inadmissibility of Beauty’s total evidence at different times.

3. *A Defense of the Thirder Position: Credence in Monday?*

A question that is rarely looked at in detail in discussions of the sleeping beauty problem is what credence Beauty should have, upon first awakening, that it is Monday.[[1]](#footnote-1) Beauty’s epistemic situation with respect to it’s being Monday or Tuesday doesn’t appear to be interestingly different from her epistemic situation with respect to how the coin lands. *Prima facie* it seems that her credence, upon first awakening, that it is Monday should be determined in a similar fashion to her credence, upon first awakening, that the coin lands heads. We have two options for determining Beauty’s credence, upon first awakening, that it is Monday. We can either determine what her credences (at various times) ought to be that the coin lands heads and calculate her credences (at various times) that it is Monday or we can apply the same line of reasoning we used in determining her credences that the coin lands heads directly to determining what her credence that it is Monday ought to be. In the absence of any reason to think that there are important epistemic differences that prevent the same line of reasoning from being applicable both to how the coin lands and to what day it is, the two routes for calculating her credence that it is Monday ought to agree.

One of the advantages of considering what Beauty’s credence, upon first awakening, that it is Monday ought to be is that straightforwardly demonstrates a strange feature of the double-halfer first noted in (Hawley 2013). In fact, any position that claims that Beauty’s credence should be the same both immediately before and immediately after learning that it’s Monday will share this feature. Let be the proposition that the coin lands heads and let be the proposition that it is Monday. Now let’s consider , the credence Beauty assigns, upon first waking, to the proposition that it is Monday and the coin lands heads. From the general multiplication rule, which is applicable regardless of whether the events in question are dependent or independent, we know that

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|  |  | (1) |

Since Beauty knows that the only experimental awakening if the coin lands heads occurs on Monday, . Therefore,

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| --- | --- | --- |
|  |  | (2) |

The general multiplication rule also tells that

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| --- | --- | --- |
|  |  | (3) |

Now is the credence Beauty assigns to heads after conditionalizing on the evidence that it is Monday; that is, . Using this, along with Equation (2), Equation (3) becomes

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| --- | --- | --- |
|  |  | (4) |

The obvious consequence of Equation (4) is that anyone who thinks that Beauty’s credence in heads shouldn’t change when she learns that it is Monday is stuck with the consequence that Beauty’s credence, *upon first awakening*, that it is Monday ought to be 1; Beauty ought to be certain that it is Monday despite knowing that it might *actually* be Tuesday. Consequently, the double-halfer position appears to be untenable.[[2]](#footnote-2)

For the halfer, on the other hand, we can see from Equation (4) that because and . First of all, it seems intuitively wrong that (and that , where is the proposition that it is Tuesday). Second, Beauty doesn’t appear to have any new information relevant to what day it is other than that it isn’t Sunday, and that it isn’t Sunday doesn’t appear to favor either or . How, then, are we to explain the difference between and ? As a result of her ignorance Beauty could rely on a principle of indifference. However, this will yield or and depending on whether Beauty thinks she ought to apply the principle to the two possibilities and or the three possibilities , , and , respectively (not to mention that the latter option amounts to accepting the thirder solution). It is not clear that there is a way for the halfer to independently justify the claim that .

Things are even worse for the halfer in that we can pose the following dilemma. Either Beauty has evidence, upon first awakening, that confirms or she has no such evidence. If she has no such evidence then presumably the credences she ought to assign are   
, which conflicts with the halfers claim that . Suppose on the other hand that Beauty does have evidence, upon first awakening, that confirms . That same evidence, of course, disconfirms . Let be the proposition that the coin lands tails. From the general multiplication rule we find that,

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| --- | --- | --- |
|  |  | (5) |

It follows that,

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| --- | --- | --- |
|  |  | (6) |

since . From Equation (6) it follows that if Beauty has evidence, upon first awakening, that ought to affect her credence that it is Tuesday then she *ipso facto* has evidence that ought to affect her credence that the coin lands tails (or heads). Consequently, if Beauty has evidence that ought to affect her credences regarding the day she also has evidence that ought to affect her credences regarding the outcome of the coin toss. This, of course, conflicts with the halfers supposition that Beauty has no such evidence. According to the halfer, the reason that   
 is that and Beauty gains no new evidence, upon first awakening, that ought to affect her credence that the coin lands heads.

In order for the halfer to be able to assign credences without also assigning credences the questions of whether Beauty, upon first awakening, has evidence that ought to affect her credences regarding the coin and whether she has evidence that ought to affect her credences regarding the day *must come apart*. She must have no evidence that will change her credences regarding the coin but must have evidence that should affect her credences regarding the day. However, I have shown that Beauty’s credences regarding the coin are functions of her credences regarding the day. Consequently, the halfer must assign credences . But, since the halfer position (understood as including the probability calculus) entails that , the halfer cannot consistently assign the credences that I have argued that they must.

For the thirder, we can see from Equation (4) that because and . The first thing to note is that there doesn’t appear to be anything intuitively wrong with Again, Beauty doesn’t appear to have any new information relevant to what day it is other than it isn’t Sunday. Consequently, the explanation of this credence assignment ought to be based on what Beauty knows about the experiment. At least two independent arguments (that is, arguments that don’t go by way of determining ) can be offered in favor of this assignment.

The first argument is that Beauty ought to use a principle of indifference to assign equal credences to , , and . The connection between the result of the coin toss and what day it is has the consequence that separately applying the principle of indifference to both the coin toss and the day leads to nonsensical results. We can see from Equations (2) and (3) that it leads to the result that . One might claim that we ought to apply the principle to either the coin or the day, but not both. However, there seems to be no reason to favor one option over the other. So, if we are going to use the principle of indifference, it seems that it ought to be applied to the three possibilities , , and . From Equation (3) we find that

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| --- | --- | --- |
|  |  | (7) |

We also have that,

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| --- | --- | --- |
|  |  | (8) |

where line 2 follows from the definition of conditional probability, line 3 from the general multiplication rule, and line 4 from the specific addition rule in addition to the fact that . From Bayes’ theorem we also find that

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|  |  | (9) |

Equating Equations (8) and (9) and solving for we get

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| --- | --- | --- |
|  |  | (10) |

While it is true that it also follows from that , this fact is not used in the above derivation. only ‘plays a role’ through , but was determined directly by use of the principle of indifference.

This argument is strengthened by the fact that in a long run of such experiments the limiting relative frequency of Monday awakenings will be 2/3. I am not claiming here (but see the next paragraph) that one’s credence ought to match this frequency, there can certainly be cases in which credence and frequency should come apart. We have an example of that in this very problem in that rather than 1/2. What I am claiming is that probabilities have a close connection to limiting relative frequencies and the fact that a probability turns out to match the limiting relative frequency ought to be taken as confirming (not verifying) that the probability is correct. That is, the fact that an argument that does not force to match the limiting relative frequency of occurrences of in a long run of sleeping beauty experiments yields a value for that does match this frequency strengthens the conclusion.

The second argument relies on the claim that because probabilities have a close connection to limiting relative frequencies, we ought to assign credences on the basis of information about limiting relative frequencies in the absence of any better information. If limiting relative frequencies are a good guide to objective chances (and I am not claiming that they are), then assigning credences in accordance with limiting relative frequencies is not only a good strategy, but, it is what one clearly ought to do in the absence of inadmissible (i.e. better) information about the outcome of interest.

Looking at limiting relative frequencies also draws attention to the fact that credence assignments regarding outcomes of the coin toss and regarding whether it’s Monday or Tuesday are treated symmetrically in the thirder case. Two-thirds of the awakenings in a long run of sleeping beauty experiments will occur on Mondays and two-thirds will also occur when the coin lands tails.

4. *Additional Arguments for the Thirder Position*

Given that it follows from Equation (4) and the fact that that , another approach to defending the thirder position is to defend that the claim that . If , then ; on the supposition that the only reasonable value for less than 1/2 is 1/3, it then follows that . I will briefly look at two reasons for accepting that

The first reason is that there do not appear to be any differences in Beauty’s total evidence on Sunday and upon learning that it is Monday that ought to make any difference to her credence in heads. Suppose we modify the experiment slightly such that, upon first awakening, Beauty knows that it is Monday. What should Beauty’s credence in heads be when she first awakens? It doesn’t appear that Beauty has any inadmissible information. Lewis’s explanation of Beauty’s inadmissible information is inapplicable to this modified version since it depends on Beauty’s learning information about the future when she learns that it is Monday: “namely that she’s not now in it” (Lewis 2001, p. 175). But Beauty can only learn that she’s not now in the future (that it isn’t Tuesday) if Beauty is ignorant of her temporal location, which she isn’t in the modified version. In the modified version, Beauty has no inadmissible evidence when she first awakens on Monday and so she should have credence 1/2 that the coin lands heads. But Beauty’s total evidence upon first awakening in the modified version is the same as her total evidence upon being told that it is Monday in the original version (though her total evidence *on Sunday* was different in that, in the modified version, she knows that she won’t lose track of the day). So Beauty’s credence, upon first awakening, that the coin lands heads ought to be 1/2 in the original version as well.

Secondly, it seems unimportant for the problem whether Beauty’s memory is erased after a Tuesday awakening, so it will do no harm to suppose that this is what happens as long as the Wednesday awakening is still distinguishable from the experimental awakenings. So Beauty wakes up on Wednesday, knowing that it is Wednesday, with no memory of the experimental awakenings: what credence should she have then that the coin landed heads? Beauty’s total evidence on Wednesday is no different than her total evidence on Sunday save for her knowledge of the day (and her irrelevant knowledge that coin has already been flipped). But knowing that it is Wednesday is irrelevant to how the coin landed and so Beauty’s credence in heads on Wednesday should equal her credence in heads on Sunday, namely 1/2. However, in between being told it is Monday and waking up on Wednesday, the only change in Beauty’s total evidence is learning that it is Wednesday. But conditionalizing on this new, irrelevant, evidence shouldn’t change Beauty’s credence. Therefore, Beauty’s credence, upon learning that it is Monday, that the coin lands heads should be the same as her credence, upon awakening on Wednesday (with no memory of the experimental awakenings). That is, .

5. *Admissible and Inadmissible Information*

Since I have claimed that Beauty ought to follow PP in the absence of inadmissible information and that , I should offer an explanation of why Beauty’s total evidence upon first awakening is inadmissible. First, recall from my criticism of the double-halfer that the setup of the problem, the probability calculus, and the fact that are enough to show that *M* confirms *H*. Consequently, knowing whether or not it is Monday affects Beauty’s credence that the coin lands heads. In other words, if Beauty knows that it is Monday or if Beauty knows *that it is not* Monday, then this will affect her credence, upon first awakening, that the coin lands heads. This gives us another way to understand the halfer position. Beauty knows neither that it is Monday nor that it is not Monday upon first awakening, and so her credence in heads upon first awakening does not change. But then, when she learns that it is Monday, her credence in heads is boosted to two-thirds.

However, understood in this way the halfer is missing something. The halfer treats as affecting Beauty’s credence in heads only when or . However, we have already seen that is a function of . Now Beauty’s ignorance when she first awakens is relevant to determining and, therefore, is also relevant to determining . But clearly Beauty’s state of ignorance is irrelevant to the objective chance of heads; her total evidence is inadmissible by definition.

Let me give a quick sketch of how I see things progressing through the experiment. On Sunday and . If were a function of , then the former would have to be undefined or zero. On Sunday Beauty’s credence in heads is not connected to her credence that it is Monday. Consequently, one relevant difference in Beauty’s epistemic state when she first awakens on Monday is that these credences are now connected. Upon first awakening on Monday Beauty must re-evaluate her credence in heads on the basis of this connection. Her ignorance of whether it is Monday or Tuesday in conjunction with her knowledge of the experiment result in an assignment of . On the basis of this assignment she then determines that . Upon learning that it is Monday, Bayesian conditionalization leads her to conclude that .

The important point to note is that the reason that Beauty’s total evidence upon first awakening is inadmissible is because of the connection that forms between her credence in heads and her credence that it is Monday. Considerations that are relevant to determining *become* relevant to determining . More specifically, it is Beauty’s knowledge that she is *now* in the experiment that is inadmissible as it is as a result of this knowledge that Beauty knows that her credence that the coin lands heads and her credence that it is Monday are connected by Equation (4). However, Beauty’s credence in Monday in inadmissible because it affects her credence in heads without affecting her credence in the objective chance of heads.

6. *Conclusion*

I have argued that considering the question of what Beauty’s credence in Monday ought to be, particularly when she first awakens, provides a new route for defending the thirder position. My primary argument for the thirder position has been an eliminative one. It relies on the assumption that the halfer, double-halfer, and thirder positions are the only reasonable possibilities, then it proceeds to show that the halfer and double-halfer positions are not, in fact, reasonable. However, this still leaves us with the puzzle of identifying Beauty’s inadmissible evidence. While I think my argument for the thirder position is worth looking at insofar as it involves considerations that are usually not found in previous discussions of sleeping beauty, I think the most important contribution of this paper regards Beauty’s inadmissible information. By examining how Beauty’s credences in and are connected, my approach provides insight into the nature of Beauty’s inadmissible evidence that licences her credence of 1/3 in heads (upon first awakening).

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1. As noted by Hawley, it is very rare for claims about Beauty’s credence that it’s Monday to be made explicitly. Notable exceptions include (Karlander and Spectre 2010), (Titelbaum 2008), and (Titelbaum 2012). But even in these cases the authors merely claim that should be less than 1 and that this implies that the halfer is committed to the claim that . There is no detailed analysis of the precise credence Beauty should have that it is Monday save for Hawley’s defense of the claim that . [↑](#footnote-ref-1)
2. But see (Hawley 2013) for a defense of the claim that . [↑](#footnote-ref-2)