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b) S1 : ~~$\exists e (buy(e, kim) \wedge e \prec n \wedge$ at(e,~~
$\exists e\,(buy(e, kim, milk) \wedge e \prec n \wedge at(e, midnight))$

S2 : $\exists e\,(buy(e, kim, milk) \wedge e \prec n)$

The semantics in S2 has one less constraint than S1. ~~Hence~~ Any logic satisfying S1 will also satisfy S2. Hence S2 is a valid consequence of S1.

The sentence "kim bought stuff at midnight" is a logical consequence of S1 because "stuff" is more general than milk.

The sentence "kim has milk" follows from S1 but its semantic representation is not a logical consequence of S1 because its logic is independent from S1

c)

w_{i-1} \ w_i	a	b	c	</s>
<s>	$\frac{2}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
a	$\frac{2}{10}$	$\frac{3}{10}$	$\frac{1}{10}$	$\frac{3}{10}$
b	$\frac{4}{11}$	$\frac{1}{11}$	$\frac{4}{11}$	$\frac{1}{11}$
c	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{2}{8}$

$P(w_i|w_{i-1}) = \frac{C(w_{i-1}, w_i)}{C(w_{i-1})}$, To avoid zero probabilities, apply add-one ~~or~~ Smoothing. The new formula is $P(w_i|w_{i-1}) = \frac{C(w_{i-1}, w_i) + 1}{C(w_{i-1}) + V}$, where $V=5$ where $C(w_{i-1}, w_i)$ is the number of occurences of w_{i-1} followed by w_i and $C(w_{i-1})$ is the number of occurences of w_{i-1} alone.

$P(\text{<s> b a b c </s>}) = P(\text{<s>}|b) \cdot P(b|a) \cdot P(a|b) \cdot P(b|c) \cdot P(c|\text{<s>})$
$= \frac{3}{8} \cdot \frac{4}{11} \cdot \frac{3}{10} \cdot \frac{4}{11} \cdot \frac{2}{8} = \frac{9}{2420}$

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d) There are 35 unseen animals (with $c=0$).

~~$P_{GT}(\text{unseen}) = \frac{N_1}{N}$~~ Using Good-Turing smoothing with $N=50$

c	N_c	c^*	P_{c^*}
0	35	$\frac{1}{7}$	$\frac{1}{350}$
1	5	$\frac{3}{5}$	$\frac{3}{125}$
2	3	$\frac{2}{3}$	$\frac{1}{25}$
3	2	$\frac{1}{2}$	$\frac{1}{25}$
4	1	/	/

I would not be inclined to fit because most of the counts for animal seen > 4 is zero, and Good-Turing would not be suitable because of zero denominator.

e) The company can use extrinsic evaluation. They can count the number of ~~emails with responses including the three short responses offered. which they consider to be appropriate~~ times when short responses are offered and selected (TP), the number of times when short responses are offered but not clicked, the number of times when responses not offered but similar messages (FP) are found in response email, and the number of times responses not offered (FN) and not similar message found (TN). Then they can Calculate the precision define by $P = \frac{TP}{TP+FP}$, and the recall defined by $R = \frac{TP}{TP+FN}$. They can use the F_1-score defined by $F_1 = \frac{2 \cdot P \cdot R}{P+R}$, which combines the precision and recall, reflecting the performance more reliably.